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A TRANSACTION WORKLOAD MODEL AND ITS APPLICATION TO A TACTICAL C^3 DISTRIBUTED DATABASE SYSTEM

The MITRE Corporation

Jeffrey L. Dawson

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This report gives a high level description of a tactical C^3 database and describes a mathematical model which derives the workload on that database as a function of user load. The model is for use in evaluation of alternatives at an early stage of system design. The model can be extended to provide data for file allocation, to derive message flow resulting from a particular file allocation, and to determine the time and magnitude of the peak load on the system. The report includes

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results of an initial investigation of the effects of mission levels and file allocation strategies on database activities, message traffic, and other performance factors, for a field-deployable tactical air control system.

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SECTION 1

INTRODUCTION

PURPOSE

A distributed database system consists of shared data distributed among geographically-dispersed computers, which are linked by a communication network. The system provides a user, at one computer, access to data stored at another computer in the network. There are two principal motivations for the use of distributed database technology for military command and control:

1. A wider range of data is available to organizational components. This is accomplished either by linking existing component databases, or through overall distributed database design.

2. Through redundant dispersed storage, critical data is less susceptible to destruction or loss.

The appropriateness of most any of the choices among design alternatives in a distributed database system is governed by the pattern of usage which drives the system. The purpose of this paper is to describe the design, implementation and use of a mathematical model, termed a transaction workload model, to derive database usage patterns in a tactical C3 setting.

The basic model takes tactical air mission levels as input, and produces measures of database activity in terms of total daily storage and retrieval operations for all files and from all nodes of the system. Extensions to the basic model allow incorporation of: (1) time lines, so that activity profiles can be derived for the time period and (2) file allocations, so that communication traffic and nodal workloads can be derived.

SCOPE

The task of Project 4560, "Tactical C3 Distributed Database Systems," sponsored by Rome Air Development Center/Information Sciences, is the investigation of applications of distributed database technology to Air Force command and control problems. This project is focused on the application of this technology to support the force management functions within the tactical air control system. These functions consist of planning, directing, monitoring,

and controlling tactical air missions. Operational requirements, along with force deployments and a 24-hour operational cycle, were derived from a modified Korean training scenario (NERA76). Detailed information requirements for a distributed database system supporting the force management functions indicated were derived from TAC Data Automation functional requirements (ESDA77). These information requirements are presented in (LAMB78a) and (LAMB78b).

In order to keep the investigation manageable and fruitful, restrictions were placed on the scope of the investigation in three areas: (1) air mission types considered, (2) the amount of component automation assumed, and (3) knowledge required of the user. These restrictions will now be detailed.

1. Air Missions

The types of missions considered here are:

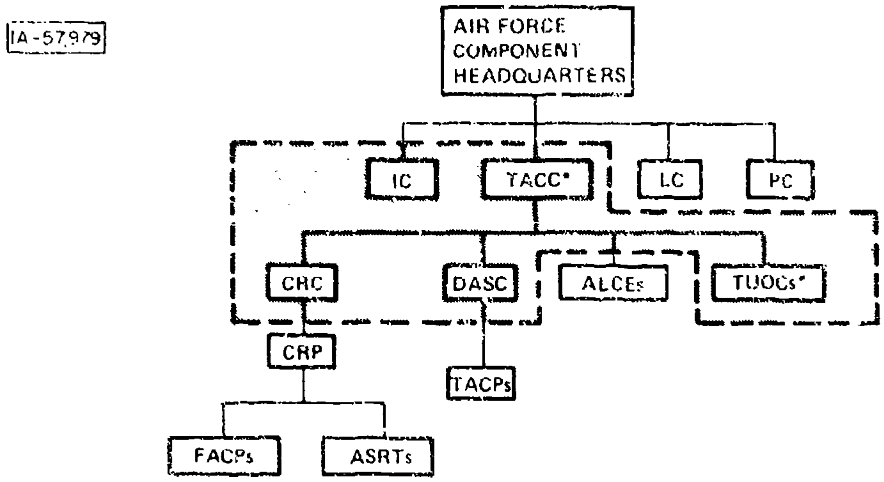
- counter air
- air interdiction
- close air support
- air defense
- reconnaissance
- combat air patrol and escort (referred to as support missions)
- air refueling (only assignment, not detailed planning)

These missions will be further categorized as preplanned, air alert, ground alert, or immediate missions. The mission types omitted from this study are:

- tactical airlift
- electronic warfare
- special operations
- search and rescue
- air refueling (detailed planning).

2. TACS Component Automation

The tactical air control system (TACS) component responsible for the force management functions is the tactical air control center (TACC) with assistance from its subordinate components. Figure 1 shows a typical organization of TACS components. Given our concept of component automation, and our restrictions on mission types and functions, the components we will concern ourselves with are those enclosed in the shaded region of Figure 1. Each of these components is assumed to be the physical site of a node of the computer network.



IC	INTELLIGENCE CENTER	FACP	FORWARD AIR CONTROL POST
TACC* (ASOC)	TACTICAL AIR CONTROL CENTER (AIR SUPPORT OPERATIONS CENTER)	ASRT	AIR SUPPORT RADAR TEAM
LC	LOGISTICS CENTER	DASC	DIRECT AIR SUPPORT CENTER
CRC	CONTROL AND REPORTING CENTER	TACP	TACTICAL AIR CONTROL PARTY
PC	PERSONNEL CENTER	ALCE	AIR LIFT CONTROL ELEMENT
CRP	COMMAND REPORTING POST	TUOC* (WOC)	TACTICAL UNIT OPERATIONS CENTER (WING OPERATIONS CENTER)

THESE TERMS WERE UNDER REVISION AT THE TIME OF WRITING AND MAY NOT REFLECT CURRENT TERMINOLOGY. *THE PARENTHESIZED TERMS ARE REVISED DESIGNATIONS, BUT WILL NOT BE USED IN THE TEXT OF THIS PAPER.

Figure 1. Typical Organization of Tactical Air Control System Components

3. User Knowledge

The user is assumed to have detailed knowledge of the contents of the database. The user must know which units of stored information are required and identify them to the database management system for retrieval. The database management system is not assumed to supply the capability to retrieve stored information according to content.

The information stored in the database is specific to the execution of air missions. In order for a user to make intelligent use of this information, he must have access to information on the current battle situation. The battle situation information may also be stored in a computer database, but it will be assumed to be separate from the database of this study.

Although the scope of investigation has been narrowed, it has been done in such a way that the functional effect of the neglected portions of the TACS on those which remain will be minimal. Moreover, our approach is modular in the sense that the omissions could be incorporated easily at a later date if desired. For instance, the force management functions for airlift missions and interaction with the Air Lift Control Element (ALCE) could be incorporated; or a new automation concept, such as more mechanized functions at the Tactical Unit Operation Center (TUOC), could be laid over the current concept.

The two extensions mentioned above are representative of more detailed or enhanced management functions. Another direction of possible expansion of the scope of this study would be the inclusion of other TACS functions. There would probably be two stages to such an undertaking: design of information storage and retrieval systems to support the functions of each of the other TACS components on the same organizational level as the TACC, the management of materiel by the logistics center for example; then design a distributed system which integrates these component databases. The present study would play an important initial role in such an expansion by providing a design for a specific component database, as well as providing a paradigm for design of components databases.

To summarize, our interest will be in a distributed database to support force management functions, for the tactical air missions listed above, with responsibility concentrated at the TACC and spread through the TACC components highlighted in Figure 1.

Summary of the Basic Model

The basic tenet of our approach is that the load on a distributed database system will be determined by the level of user activity which drives the database. The basic transaction workload model reflects this transformation of user activity into database load. To formulate such a model, one needs to define parameters for measuring user activity, parameters for measuring database load, and a mapping from the former to the latter.

The amount of user activity is directly related to the number of tactical air missions executed during the day. So, we use mission levels during a 24-hour cycle as our user activity parameter.

A first approximation to a database system, satisfying the basic information storage and retrieval requirements, is defined by a small set of very general files along with rudimentary file operations. This system will be referred to as the information system. To parameterize database load in the information system, counts will be kept of each of the file operations, which file was affected, and the source of entry of the operations.

The mapping from user activity to database load represents the patterns of data usage in carrying out the force management functions. We create a script of probable user actions necessary to carry out the force management functions. Each action identifies a file, a file operation, and the source of entry of the operation. Each action of the script is assigned a frequency with which it is likely to occur. The frequency is dependent on user activity. The quantified script provides the mapping from user activity, in mission levels, to information system activity, in file operation counts.

The quantified script provides a flexible and justifiable format for the model. The motivation for inclusion of each action can be justified. Actions can be removed, added, or modified as the need arises.

Extensions of the Model

The results from this basic model can be used for more detailed modeling of a database system, as well as for early design consideration. Two extensions to the basic model are considered in this paper. One reflects an operational time line for varying user activities. The other considers the effect of allocation of data files within the network.

The operational time line is represented by associating an interval of occurrence to each of the actions of the quantified script. Since each action of the quantified script is linked with execution of the force management functions, we assign time intervals to each of the functions to obtain times for the actions. With this time line we can determine the rate at which the various database activities occur during the day.

When data files have been allocated among the nodes, we can begin to determine the communication and node processing loads. A file operation entered from a node, other than that holding the file, will require a message to be sent. Thus, knowing the sources of file operations and the locations of the files, we can determine internode message counts. By examining the incoming message at a node, we can measure processing requirements at each node.

Contents of Paper

The structure of the database, upon which our model is based, is described in Section 2. We include only enough detail of the system to enable generation of quantitative information for subsequent stages of system design. The general construction of the basic transaction workload model and its operation are discussed in Section 3.

The representation of tactical air operation, as viewed by the model, is described in Section 4. Output from the basic model representing five different operational scenarios is presented and discussed in Section 5.

The basic model is extended to include an operational time line. This provides rates of database activity during the day. This data is presented in Section 6.

The location of data files within the network is discussed and extensions are made to the basic model to include file location. Data provided by this extension is presented in Section 7.

Section 8 summarizes the information gained from the transaction workload model and its extensions.

SECTION 2

INFORMATION SYSTEM

GENERAL DESCRIPTION

The information system, on which we will be basing our model, consists of a small number of simply structured logical files and of rudimentary operations performed on those files.

The logical files, which are listed in Table 1, were obtained by aggregating relational data structures defined in (LAMB78b). Those relational data structures are mission-dependent in definition. To reduce the complexity, similar data for differing mission types have been unified into single files. We will need only a general notion of the contents of the files, although a more detailed description could be derived. Appendix A details the correspondence between our logical files, and the relations of (LAMB78b).

Each logical file will comprise a collection of logical records. Every logical record is assumed to have a unique identifier or key through which operators gain access to individual records. Knowledge of the specific data content, fields, or structure of the logical records will not be necessary at this time, although these could be derived from (LAMB78b).

The file operations allowed will all be record-at-a-time operations. That is, if any portion of a logical record is to be retrieved or altered, then the entire record must be retrieved or altered. The file operations are the following:

INSERT - A new logical record is added to an existing file. The system provides an access key.

DELETE - The logical record, whose key is specified by the user, is removed from the file.

RETRIEVE - The contents of a logical record, whose key is specified by the user, are displayed to the user.

REPLACE - The entire contents of a logical record, whose key is specified by the user, are replaced by user supplied data.

Table 1

Logical Files

File Name	Content
TARGET	Target list. Includes location and description of each target.
MSN_REQ	Request for a preplanned mission. Includes location and mission type, target identification, materiel recommendations, etc.
SUP_MSN_REQ	Support mission request.
MSN_SCHED	Mission schedule. Includes mission type, aircraft type, air unit, etc. This is the gross wing level mission assignment done primarily at the TACC.
FLIGHT_SCHED	Flight schedule. Includes takeoff and landing times, time on target, etc. This is the detailed squadron level planning done at the TUOC.
TNKR_ASGMNT	Tanker assignment. Contains only a general assessment of refueling needs. We do not consider detailed tanker mission planning in this report.
REPORTS	Mission progress reports.
IMMED_MSN_REQ	Request for immediate reaction mission.
ALERT	Ground and air alert resources available. Includes a record for each mission currently on alert.
CRITICAL_MUNITIONS	A list of those munitions in short supply.
TACS_STATUS	Operational status of each tactical air control system component.
AIRBASE_STATUS	Operational status of equipment at each airbase.
AIRCRAFT_STATUS	Readiness condition of each type of aircraft and air crew at each airbase.
SORTIE_AVAIL	Sortie availability for each air unit.
SORTIE_RATE	Sortie rate for each aircraft type and air unit.
OVERALL_APPORT	Overall apportionment of sorties available to mission types.
UNIT_APPORT	Apportionment to mission types by air unit.

There will be five types of nodes within the distributed system being modeled, which are consistent with the TACS components mentioned in the introduction:

TACC - Tactical Air Control Center

TUOC - Tactical Unit Operation Center

DASC - Direct Air Support Center

CRC - Control and Reporting Center

IC - Intelligence Center

Though there may be replication of some of these components for a given system deployment, e.g., there are eight TUOC's in the deployments of (LAMB78a), they will be considered equivalent to a single "average" node in the network for this model. The nodes will be of interest to us as the sources from which the file operations originate. They will also be candidate sites for location of the logical files when we are ready to include that detail.

OVERVIEW OF INFORMATION SYSTEM USE

The functions which our information system is to support are planning, monitoring, directing, and controlling of tactical air missions. We can interpret these functions as follows with regard to our information system:

Planning - Insertion of data for specific missions into the database.

Monitoring - Checking stored data to insure its agreement with the physical situation or overall plans.

Directing - Making data available to components needing it. The sending of orders or directives is automatic in the system envisioned. Orders are posted in the database, and the recipient retrieves them.

Controlling - Updating or changing stored data in reaction to changing situations.

One further function, which we will call data maintenance, consists of loading or purging data as the need arises.

We will present an outline of the manner in which the information system is used for the planning function over the 24-hour cycle. This will provide an indication of the purpose of each logical file, and provide a background for more detailed discussions in Section 4.

The cycle for preplanned missions begins with storage of information on targets (TARGET) and requests for missions against those targets, along with recommendations on carrying out the missions (MSN_REQ). After the available aircraft have been allocated among the mission types, planners at the TACC begin retrieving mission requests and their corresponding targets, and scheduling missions in response to these requests. This wing level mission scheduling information (MSN_SCHED) is stored, so that it can be reviewed later in its totality, and then retrieved at the TUOC for more detailed squadron level scheduling (FLIGHT_SCHED). As the missions are put into operation and carried out, mission progress is monitored through reports which are stored (REPORTS). Returning to the wing level mission scheduling for a moment, it may be that some of these missions require support missions. Thus, the planner at the TACC would enter a support mission request (SUPP_MSN_REQ) for later processing. The support missions will give rise to their own mission schedules, flight schedules, and reports which will also be stored. When wing level mission scheduling has been done, air refueling requirements can be determined and tanker missions assigned (TNKR_ASGNMT). We do not consider detailed tanker mission scheduling, since this is carried out by an organizational entity outside the scope of our investigation.

Information activity for mission assignment and execution is characterized by the insertion of certain logical records in an approximate chronological sequence. This sequence will be used to help decompose the 24-hour operational cycle into phases. An information structure for preplanned missions can be conceived as a set of linked logical records as shown in Figure 2. The links need not be one-to-one; for example, many TARGET records may be linked to a single MSN_SCHED record implying multiple targets for a single mission. Or, a ground alert MSN_SCHED would have no TARGET record linked. The information structure of Figure 2 can be thought to grow from left to right as insertions are made during the life cycle. The captions in the lower margin identify the chronological phase during which the records above are inserted. The captions of the left margin identify the mission types to which the adjacent records pertain. Primary missions comprise all preplanned missions other then support missions.

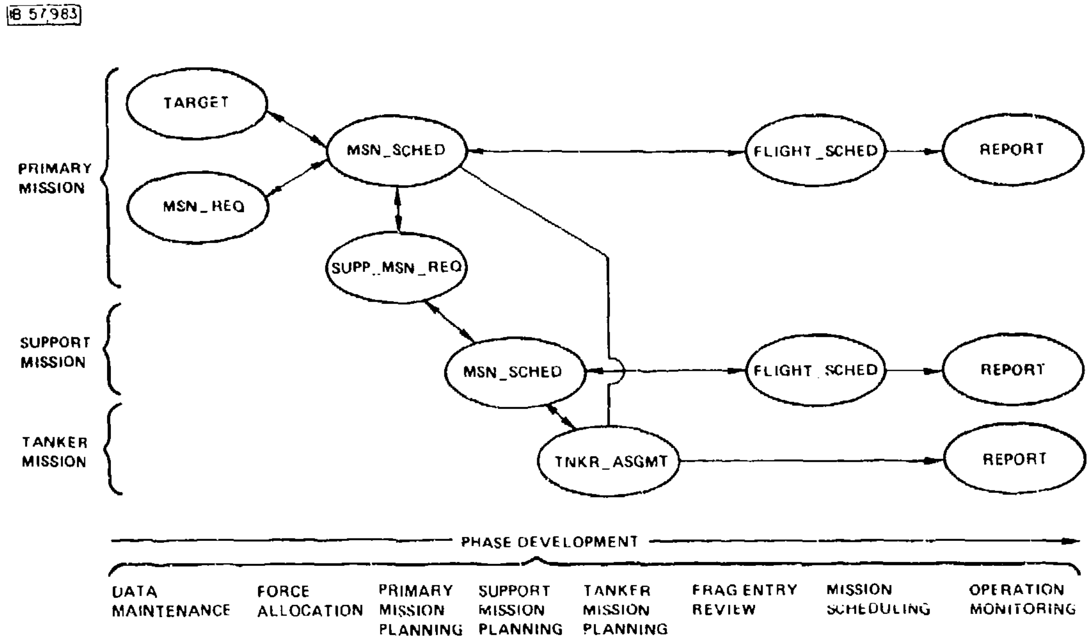


Figure 2. Preplanned Mission Information Structure

The activity of immediate mission planning is performed in real time response to immediate mission requests entered in the database, as opposed to the systematic manner in which preplanned missions are laid out. A planner has the option of either activating a mission on alert, or diverting a mission in progress. In either case, the primary information activity will be updating existing records. If an alert mission is activated, its MSN_SCHED is updated to indicate that it is an active mission. It will be linked to a TARGET record, and supplied with a FLIGHT_SCHED record if it was a ground alert. To divert a mission in progress, a new or additional TARGET will be linked, and changes may be made in the MSN-SCHED and FLIGHT_SCHED records. An information structure for alert missions is shown in Figure 3.

This discussion has been only an outline of information activity. In order to construct a record to be inserted, an operator will have to retrieve and consult much information already stored. For example, before scheduling a mission a planner must know what resources are available and their location. These activities and more will be described in Section 4.

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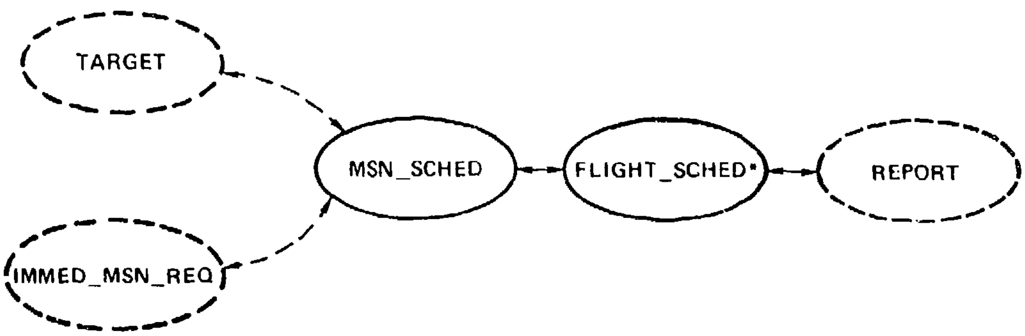

DOTTED ENTITIES WILL BE SUPPLIED ON MISSION ACTIVATION.

*GENERATED FOR AIR ALERT OR ACTIVATION ONLY.

Figure 3. Alert Mission Information Stiucture

SECTION 3

BASIC MODEL

We will briefly discuss the computational structures used for the basic model. A more detailed account is given in Appendix B.

The three types of items which specify the information system described in Section 2 are:

. logical files

. logical file operations

. sources of entry of logical file operations

These items are reviewed in Figure 4. The parameters which will be

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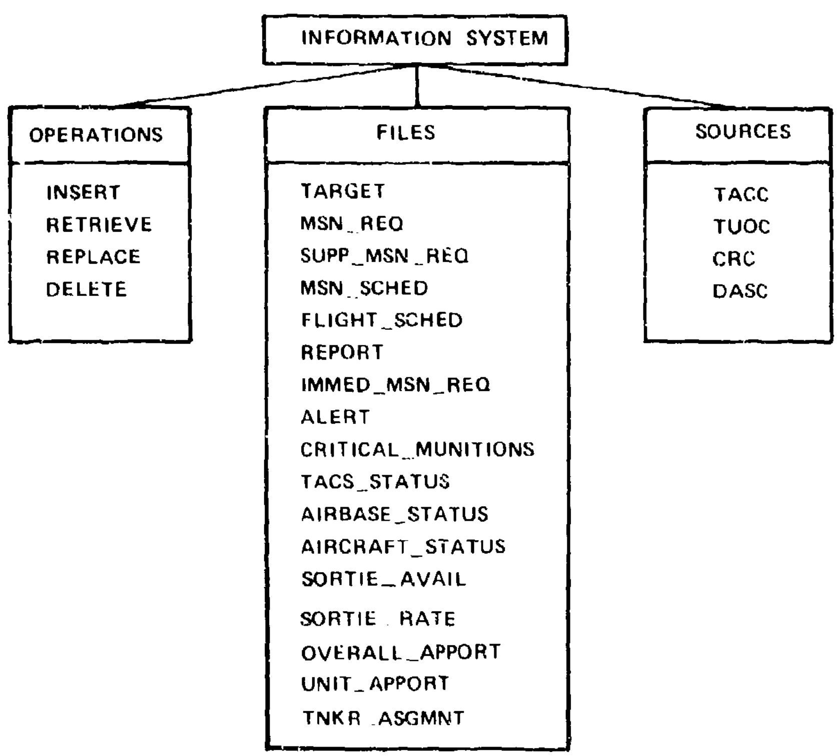

Figure 4. Information System Constituents

used to measure information system activity, and represent output to this stage of modeling, are counts of particular operations, to particular files from particular sources; for example, the number of INSERT operations to the MSN_REQ file originating from the DASC as source. The counts are assembled in a three-dimensional array whose dimensions represent operations, files, and sources. Thus, the triple (INSERT, MSN_REQ, DASC) can be used to locate a position in the array of counts, and the corresponding count will be stored there. The array will be referred to as the file activity array.

The input to the model will be counts of the various types of air missions that are planned and executed during the 24-hour period being modeled. The tactical air missions counted are shown in Figure 5.

PREPLANNED
- OFFENSIVE COUNTER AIR
- AIR INTERDICTION
- CLOSE AIR SUPPORT
- RECONNAISSANCE

AIR ALERT
- AIR DEFENSE
- AIR INTERDICTION
- CLOSE AIR SUPPORT

GROUND ALERT
- AIR DEFENSE
- AIR INTERDICTION
- CLOSE AIR SUPPORT
- RECONNAISSANCE

IMMEDIATE
- OFFENSIVE COUNTER AIR
- AIR INTERDICTION
- CLOSE AIR SUPPORT
- RECONNAISSANCE

SUPPORT

14-58,069

Figure 5. Tactical Air Missions

To perform the calculations for the model, a list of probable operator actions is compiled. Each action will contribute to only one of the counts in the file activity array. For example, an operator action would be the entry at the DASC of the day's mission requirements in support of ground forces. This action could affect the count located at the position in the array indexed by (INSERT, MSN_REQ, DASC). The increment to that count will be computed based on the mission counts. For example, suppose that it is determined empirically that 20 percent of reconnaissance requests, 80 percent

of close air support requests, and no others originate at the DASC. Moreover, requests exceed actual missions by two to one. Thus, to determine the increment to the count, one doubles the number of reconnaissance and close air support missions, takes 20 percent of the former and 80 percent of the latter. Each action is described by identifying the count in the file activity array to be changed and by providing a computational expression for the increment in terms of the input.

The computer implementation is based on a file, each of whose records describes an operator action in the position-increment form. The operator action file will be referred to as a script. A computer program processes each record of the script file with the mission counts, and augments the file activity array. When the entire script is processed, the array is on its final form and ready for output or further processing.

This file formats a very flexible representation of usage patterns, since actions can be inserted, deleted or altered in the file. Moreover, since each action is closely tied to the user functions being supported, as the next section will show, the justification for each action can be examined.

SECTION 4

TACTICAL AIR OPERATIONS

In this section we will describe tactical air operations, as viewed by the model, and list the operator actions necessary to carry out the operations. The representation of these actions in quantifiable form for use in the computer implementation is relegated to Appendix B.

The cycle of tactical operations is generally decomposed into four major phases. For the purposes of our modeling we will further refine this decomposition. The units for the model will be referred to as operational phases. There is a chronology to the phases which will be discussed in more detail in Section 6. The operational and major phases are listed and related in Table 2.

Table 2

Phases of Tactical Air Operations

Major Phases	Operational Phases
Mission Planning	Force Allocation Primary Mission Planning Support Mission Planning Tanker Mission Planning Frag Entry Review Flight Scheduling
Monitoring and Assessment of Operations	Operation Monitoring
Adjustment and Replacing of Operations	Immediate Mission Planning Operation Adjustment
Maintenance of Data and Report Generation	Data Maintenance

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We will now describe the nature of each of the operational phases and then list the operator actions of that phase. The actions are not necessarily in chronological order within the phases.

FORCE ALLOCATION

This task comprises determination of the number of sorties available, and allocation of these sorties among the mission types in accordance with command guidance. It is assumed that command guidance, entered as percentages, will resolve any contention for resources among different mission types. The database activity during this task is independent of the mission level, since it consists primarily of scanning files. Thus, it will be a fixed overhead depending only on the size of the files scanned.

1. Status of each airbase is checked to determine whether or not sorties can be flown.

2. Status of aircraft/aircrew at each airbase is checked to determine the equipment available.

3. The sortie rate for each type of aircraft at each airbase is multiplied by the number of aircraft available at that airbase to give the number of sorties available.

4. The computed number of sorties for each aircraft type at each airbase is stored.
5. The overall apportionment by mission type, which embodies command guidance, is stored.

6. The distribution of sorties available at each airbase from each squadron among the mission types is stored.

PRIMARY MISSION PLANNING

Planners at the TACC assign the allocated available sorties to missions. The result of this phase will be mission schedules (MSN_SCHED), one for each primary mission planned. (Primary missions comprise the Preplanned, Air Alert, and Ground Alert categories shown in Figure 5.) In order to produce each of these mission schedules, the planner will need to consult the mission request and the corresponding target data, determine the availability of munitions critical to the mission, request any support missions thought necessary, and update the number of

aircraft still unassigned. The TUOC whose aircraft are being assigned to the mission may check the mission schedules as they are generated to detect any incongruities.

1. Planner inserts mission schedule for primary mission.

2. Planner views a number of requests before deciding which request for a primary mission to fill.

3. Planner views target data for some or all of the requests viewed in #2.

4. Planner enters a request for a support mission, if it is needed.

5. To make sure all munitions needed for a primary mission are available, the planner may scan the list of munitions in critical supply.

6. As soon as a primary mission is scheduled, the planner subtracts the number of sorties used from the number of sorties available for subsequent primary missions.

7. When a mission has been planned, the DASC may want to review its mission schedule.

8. CRC may review mission schedule.

9. TUOC may review mission schedule.

SUPPORT MISSION PLANNING

In response to the support mission requests, a TACC planner generates a mission schedule for each escort or air patrol mission. A single support mission may support a number of primary missions. We will assume that the support resources have been separately allocated so that there is no contention for aircraft between combat and support missions. The planning process is roughly the same as for primary missions.

Assumption: Support resources are not sufficient to fill all requests for support. Hence, the number of support missions will be part of the input to the model. The alternative is to determine empirically the percentage of primary missions requiring support. Then the number of support missions could be computed from the number of primary missions.

1. Planner inserts mission schedule data for a support mission.

2. Planner views a number of requests for support before deciding which one (or ones) to fill.

3. Planner views schedules of preplanned missions to be assisted by the support mission being planned.

4. The list of critical munitions may be scanned to make sure all munitions are available for the support mission being planned.

5. Sorties used are subtracted from the sorties available.

6. When the support mission has been planned, the TUOC may review the mission schedule for inconsistencies.

7. CRC reviews support mission schedule.

8. DASC reviews support mission schedule.

TANKER MISSION PLANNING

When primary and support missions have been planned, a tanker mission planner at the TACC can review the mission schedules to determine which missions will need refueling and assign tanker missions (TNKR_ASGNMT) accordingly.

1. Planner enters a tanker assignment into the database.

2. Planner scans all missions to determine which missions will need refueling.

3. Planner views mission schedules of missions to be refueled by tanker being assigned.

FRAG ENTRY REVIEW

The gross mission schedules for primary, support, and tanker missions, generated so far, are reviewed to verify overall consistency and coordination of the plan for the day's tactical air operations. Alterations may be required to correct deficiencies.

1. Each of the schedules will be reviewed at least once to insure overall consistency of the frag order.

2. Some mission schedules reviewed may require alteration.

3. Mission requests may be rechecked.

4. Target data may be rechecked.

5. The tanker assigned to the mission may be reviewed.

6. Tanker assignment may require alteration.

FLIGHT SCHEDULING

The detailed mission assignment at the squadron level (FLIGHT_SCHED) is done at the TUOC in accordance with the wing level directives of the mission schedules. We will not be considering tanker flight scheduling for this model.

1. Each air mission must be assigned a flight schedule by the TUOC.

2. The mission schedule of each air mission must be viewed at the TUOC before a flight schedule can be chosen.

3. The planners at TACC may check the flight schedules for overall consistency.

OPERATION MONITORING

Mission progress reports for active missions will result in either updates to existing mission assignment data, or entry of mission results in the REPORT file. Table 3 summarizes the report type and data altered.

The progress of the ground alert missions will be tracked by updates to the ALERT file. When a ground alert mission is begun, a record is inserted in the file. When the alert is over or the mission is activated, the record is deleted from the file. Thus, there will be one insertion and one deletion for each ground alert mission. The file is reviewed in handling immediate mission requests.

1. Mission schedule is changed by the TUOC to reflect the reduced number of aircraft as the result of aborts.

2. TUOC enters an abort report.

Table 3

Mission Reports

Report Title	Frequency	Source	Data Affected
Mission Cancel	2% of missions	TACC	All
Abort	5% of missions	DASC, TUOC	FRAG_ENT
Air Advisory	2% of missions	TUOC	MSN_SCHED
Ground Delay	2% of missions	TUOC	MSN_SCHED
Takeoff	1/mission	TUOC	MSN_SCHED
Landing	1/mission	TUOC	MSN_SCHED
Refueling	1/refuel	CRC	REPORT
Reconnaissance Inflight	1/target	CRC, DASC, TACC	REPORT
Fighter Inflight /Airstrike	1/target	CRC, DASC	REPORT

3. Mission schedule changed by DASC as a result of abort.

4. DASC enters an abort report.

5. Revised flight schedule as a result of air advisory entered by TUOC.

6. Flight schedule revised by TUOC as a result of ground delay.

7. Takeoff and landing reports are entered by TUOC on the flight schedule for each mission not cancelled.

8. One refueling report is received and entered by CRC for each mission refueled.

9. Inflight report received and entered by CRC.

10. Inflight report entered by DASC.

11. Inflight report entered by TACC.

12. Missions alerted are put on an current alert resources list by the TUOC.

13. As missions go off alert without being activated, they are removed from the alert resources list by the TUOC.

IMMEDIATE MISSION PLANNING

Missions will be planned by the TACC to meet immediate situation requirements which it detects itself, or as reported by the DASC. After processing an immediate mission request, there are three possible modes of response listed here in their order of preference: directing an air alert mission to the target, activating a ground alert mission, or diverting a preplanned mission to the target.

Process Immediate Mission Request

When a request is placed for an immediate mission by the TACC or DASC, it is unlikely that the required target information is stored; this information would be inserted. In response to an immediate request, a TACC planner reviews the request and target data, then chooses an appropriate mode of response. The available alert resources are reviewed and mission schedules of any suitable missions are inspected. If no alert mission is found suitable, the mission schedules of preplanned missions are scanned until a mission is found suitable for diversion.

Assumption: Each immediate mission request results in an immediate mission being scheduled. No requests are left unfilled. Thus, the number of requests equals the number of missions.

1. Requests for immediate missions entered from the TACC.

2. Request entered from the DASC.

3. Target data of corresponding immediate mission is entered by TACC.

4. Target data entered for DASC request.

5. Planner retrieves a number of immediate mission requests before deciding which to fill.

6. Planner views target data at least once for each request filled, but may also view targets in choosing request to process.

7. Planner scans list of alert resources to determine whether or not any of these are appropriate for the immediate mission request.

8. Planner views the mission schedule of an alert mission for possible activation.

9. Planner views mission schedules of preplanned missions for possible diversion.

Activate Air Alert Mission

When an air alert mission is to be activated, the TACC must make changes to the data in its mission schedule, change mission type from alert, insert target, etc. The request should be marked as filled and the available alert resources list updated. The TUOC scheduler will make changes in the flight schedule.

10. Mission schedule of activated mission is altered.

11. Flight schedule is updated.

12. Request marked filled.

13. Mission removed from the alert resources list.

Activate Ground Alert Mission

The database activities would be the same as those for an air alert mission with the exception that a flight schedule must be inserted by the TUOC, rather than updated.

14. Mission schedule for activated ground alert mission is altered.

15. Flight schedule is entered by TUOC.

16. Request is marked filled.

17. Mission is removed from the alert resources list.

Divert Preplanned Mission

The mission schedule of a diverted mission will be changed to reflect a new or additional target, and the flight schedule may have to be altered. The refueling and support mission requirement may need change as well.

18. Change mission schedule to divert.

19. Request is marked filled.

20. Update the flight schedule.

21. Adjust tanker assignment to fill refueling needs.

22. Adjust support mission coordination.

OPERATION ADJUSTMENT

The adjustments in this phase are those which arise because of deviations from previous plans, time delays, resource shortages, mission cancellation or abort reports. The adjustment of one mission may require adjustment of other missions in order to maintain coordination. For example, the adjustment of a combat mission may necessitate adjustments to its supporting and refueling missions; or conversely, adjustment of a tanker mission will affect the mission it refuels. We will assume that the total effect of all of these interactions is reflected in the models computations.

1. Mission schedule of cancelled mission is removed by TACC.

2. Flight schedule of cancelled mission is removed by TUOC.

3. Request for support mission required by cancelled mission is removed by TACC.

4. Mission schedule of a mission supporting a cancelled mission is adjusted.

5. Assignment for a tanker mission refueling a cancelled mission is adjusted.

6. Mission schedule is adjusted.

7. Flight schedule is adjusted by TUOC due to air or ground delay.

8. Tanker assignment adjusted to maintain rendezvous with delayed mission.

DATA MAINTENANCE

We will not consider the database activity for report generation in this model, although it can be added later. The activities of this operational phase consist of maintaining data on the status of TACS components, entry of planning information for the next day's missions, and removal of out-of-date planning information.

For resources necessary to operations of the tactical air control system, the maintenance of stored information is done primarily through periodic status reports from the various units of the system as shown in Table 4. A report will consist of updating a time stamp to indicate that a report has been made, then making any appropriate revisions to the stored information.

Table 4

Status Reports from TACS Components

Report/File name	Source	Frequency
TACS Component Status	CRC, TUOC DASC, TACC	Every 4 hours/unit
Aircraft Status	TUOC	3/day/unit/location aircraft type
Airbase Status	TUOC	1/day
Critical Munitions	TUOC	1/day

1. CRC enters status report.
2. TUOC enters status report.
3. DASC enters status report.
4. TACC enters status report.

5. Each TUOC reports three times daily on the status of its aircraft and aircrews.

6. Each TUOC reports daily on the status of the airbase equipment.

7. Munitions which have reached critically low levels are entered on a list.

8. Munitions which have been resupplied are removed from the critical munitions list.

9. Mission requests entered by DASC.

10. Mission requests entered by IC.

11. The target data for the next day's mission is entered in the database.

12. Mission requests purged.

13. Mission schedules purged.

14. Old target list purged.

15. Support mission requests purged.

16. Flight schedule purged.

17. Old reports purged.

SECTION 5

RESULTS OF THE BASIC MODEL

In this section we will describe some of the results obtained from the basic model. As yet we have made no mention of the location of the files. The information obtained at this stage of the modeling is intended primarily to assist in optimal placement of the files within the network; this will be taken up in Section 7. Some of the questions that we will be able to answer in this section are:

- Who will be the heaviest users?

- Which are the most active files?

- What are the strongest user-file ties?

We can also investigate the changes in the answers to these questions as a result of changes in mission level input.

The mission levels and computational constants used in constructing and driving the present version of the model were derived from a training scenario for a Korean deployment as described in (NERA76). The computational constants we refer to are parameters such as the ratio of tanker missions to fighter missions or the average numbers of targets per fighter mission.

The effect of variation in mission levels on database activity is one of the primary interests of this work. The scenarios used were all derived as variations on the Korean training scenario. All aspects, other than mission levels, are assumed to be the same as those of the training scenario. The scenarios are as follows:

STP1 - The basic mission levels taken directly from the scenario.

STP1MAX - All mission levels were raised by 50 percent.

STP1MIN - All mission levels, except reconnaissance, were lowered by 60 percent. Reconnaissance missions stayed at the basic level.

STP1OCA - All suitable multi-mission aircraft in the STP1 scenario were shifted to offensive counter air or air interdiction missions.

STP1CAS - All suitable multi-mission aircraft in the STP1 scenario were shifted to close air support missions.

The mission levels for each of these scenarios are shown in Table 5. Each set of mission levels was entered in the model and the resulting file activity array accumulated. The array was subjected to additional processing to produce data tailored to our interest.

Table 5

Scenario Mission Levels (Number of Missions/Day)

Mission Type	Scenario				
	STP1	STP1MAX	STP1MIN	STP1OCA	STP1CAS
Preplanned Offensive Counter Air	34	51	11	34	20
Preplanned Air Interdiction	10	15	3	50	1
Preplanned Close Air Support	20	30	6	0	43
Preplanned Reconnaissance	52	78	52	52	52
Air Alert Air Defense	7	11	2	7	7
Air Alert Air Interdiction	6	9	2	0	0
Air Alert Close Air Support	5	8	1	0	11
Ground Alert Air Defense	3	5	1	3	3
Ground Alert Air Interdiction	4	6	1	0	0
Ground Alert Close Air Support	5	8	1	C	9
Ground Alert Reconnaissance	48	72	48	48	48
Support	6	9	2	6	6
Immediate Offensive Counter Air	10	15	3	10	10
Immediate Air Interdiction	10	15	3	0	0
Immediate Close Air Support	10	15	3	0	20
Immediate Reconnaissance	48	72	48	48	48
Total	278	419	187	258	278

The percentage of total database usage for each of the TACS components is shown in Table 6. The figure listed for the TUOC represents the combined usage of the eight TUOCs of the scenario. As one might expect from the scope of the study, the highest usage is by the TACC.

The most active files can be identified from Table 7, which shows the percentage of total file activity aimed at each of the files. Note that the CRITICAL_MUNITIONS file is one of the most

Table 6

Database Usage by TACS Components (Percent of Total Daily Usage)

Component	Scenario				
	STP	STP1MAX	STP1MIN	STP1OCA	STP1CAS
TACC	78.08	76.74	71.69	77.55	75.45
TUOC	11.61	11.51	12.39	11.14	11.76
CRC	2.67	2.58	2.51	2.98	2.41
DASC	4.83	5.08	6.78	4.16	6.21
IC	2.82	4.09	6.64	4.17	4.17

Table 7

Scenario File Activity (Percent of Total Daily Usage)

File	Scenario				
	STP1	STP1MAX	STP1MIN	STP1OCA	STP1CAS
TARGET	8.09	7.90	9.76	9.53	7.52
MSN_REQ	13.98	11.66	19.68	15.25	13.83
SUP_MSN_REQ	0.29	0.30	0.14	0.13	0.44
MSN_SCHED	24.50	25.47	27.26	22.84	26.02
FLIGHT_SCHED	5.54	5.76	5.20	5.67	5.66
REPORT	2.43	2.52	2.07	3.19	2.02
IMMED_MSN_REQ	1.93	2.00	2.30	1.32	1.98
ALERT	12.09	12.53	15.24	8.55	12.35
CRITICAL_MUNITIONS	27.63	28.91	13.63	29.95	26.69
TACS_STATUS	0.45	0.31	0.74	0.46	0.46
AIRBASE_STATUS	0.11	0.08	0.18	0.11	0.11
AIRCRAFT_STATUS	0.88	0.61	1.43	0.90	0.90
SORTIE_AVAIL	1.59	1.58	1.81	1.63	1.63
SORTIE_RATE	0.22	0.15	0.36	0.22	0.22
OVERALL_APPORT	0.01	0.00	0.01	0.01	0.01
UNIT_APPORT	0.08	0.05	0.12	0.08	0.08
TNKR_ASGMNT	0.17	0.17	0.09	0.17	0.09

active. This is a result of the fact that the contents of that file are scanned frequently during planning, giving rise to a large number of retrievals.

As an indication of the size to which the files may grow, Table 8 shows the total number of inserts made to each file during the 24-hour cycle. Note that records are never inserted in TACS_STATUS, AIRBASE_STATUS, or SORTIE_RATE. These are seen as permanent files of fixed lengths which are only updated.

Table 8

Scenario File Insertions (Number of Insertions/Day)

File	Scenario				
	STP1	STP1MAX	STP1MIN	STP1OCA	STP1CAS
TARGET	178	200	154	148	168
MSN_REQ	778	778	778	778	778
SUP_MSN_REQ	18	27	5	6	27
MSN_SCHED	200	302	130	200	200
FLIGHT_SCHED	208	313	133	197	208
REPORT	177	266	95	227	144
IMMED_MSN_REQ	78	117	57	58	78
ALERT	78	119	56	58	78
CRITICAL_MUNITIONS	2	2	2	2	2
TACS_STATUS	0	0	0	0	0
AIRBASE_STATUS	0	0	0	0	0
AIRCRAFT_STATUS	96	96	96	96	96
SORTIE_AVAIL	32	32	32	32	32
SORTIE_RATE	0	0	0	0	0
OVERALL_APPORT	1	1	1	1	1
UNIT_APPORT	11	11	11	11	11
TNKR_ASGMNT	5	8	2	5	2
Total	1862	2272	1552	1819	1825

SECTION 6

TIME LINE EXTENSION TO THE BASIC MODEL

The results shown in Section 5 applied to the entire 24-hour planning and execution cycle. This time period is too long to provide the amount of detail required for much of the analysis. We should like to answer questions such as:

- What is the time of peak activity?

- What are the peak loads?

- How large will the files grow?

- When is each TACS component busiest?

To provide the type of information needed, we augment the structure of the basic model with a time line. We obtain the time line by assigning a duration end to each of the operational phases.

The time line upon which the results of this section are based is shown in Figure 6, and is only hypothetical. The 0th hour is an arbitrary starting point for the cycle. The time line by which

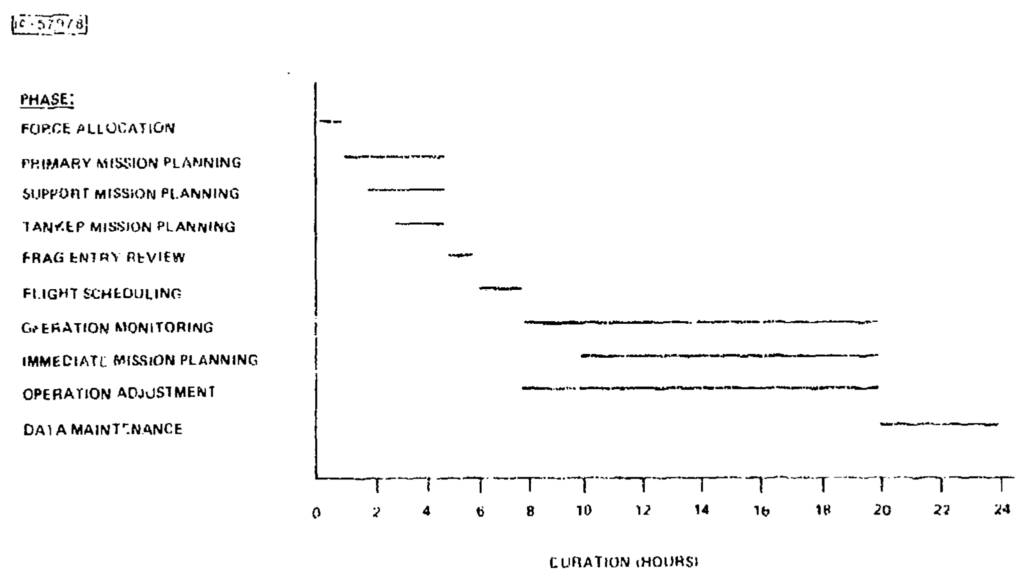

Figure 6. Operational Time Line

tactical air operations are carried out will profoundly affect the performance and design of a distributed database system. The effect certainly warrants future investigation to which our model is well suited.

Activity rates for each of the five scenarios are graphed in Figure 7. Notice that the rates for the STP1, STP1MAX, and STP1MIN maintain a reasonably constant relationship to one another. On the other hand, STP1OCA requires more planning and less adjustment than STP1, while STP1CAS requires less planning than STP1.

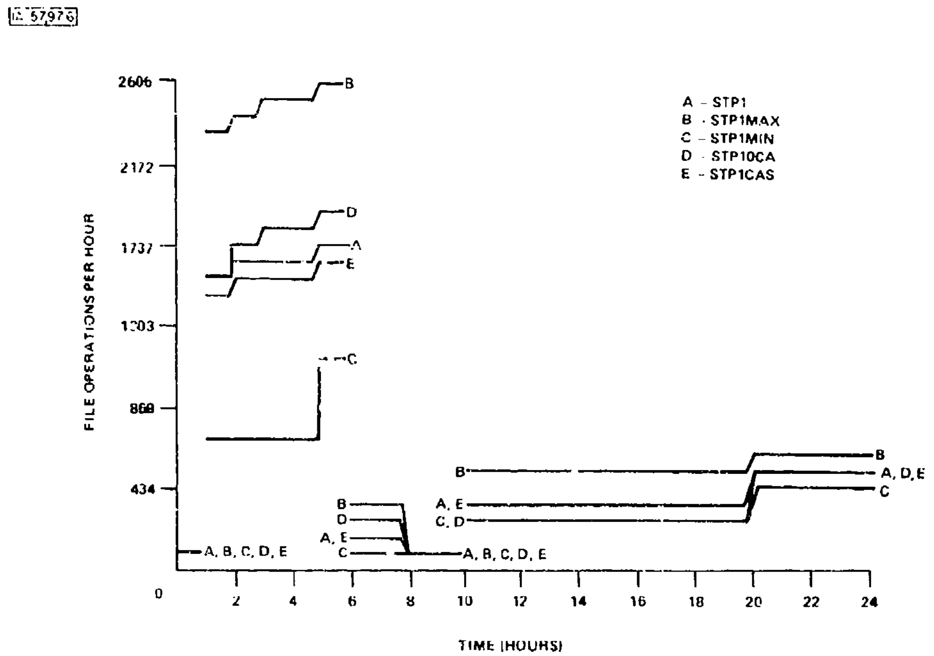

Figure 7. System Activity Levels

We would also like to know the effect of changing the mix of mission levels on the relative activity levels of each of the TACS components. These changes in mix are represented through scenarios STP1, STP1OCA, and STP1CAS. Figures 8, 9, and 10 present graphs of activity levels for each of the components. Each graph pertains to a separate scenario. The activity levels from each scenario over 24 hours are broken down by TACS component in Figures 11 through 15. The units for all of this data are file operations per hour.

IA-57,969

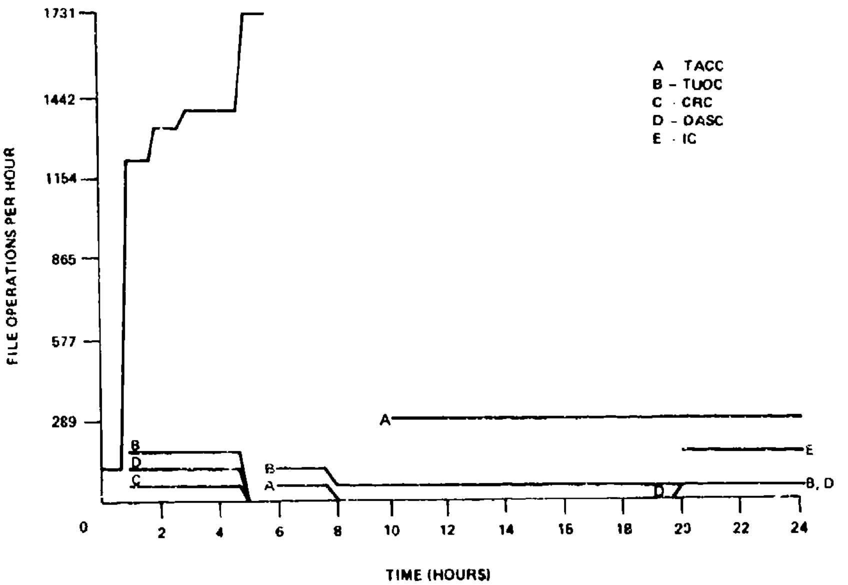

Figure 8. Component Activity Levels (STP1)

IA-57,975

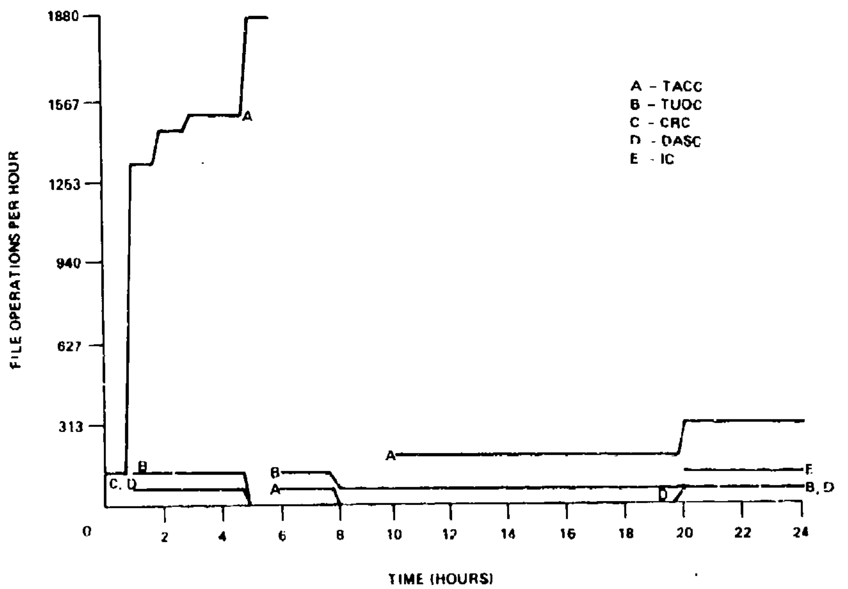

Figure 9. Component Activity Levels (STP10CA)

IA-57,974

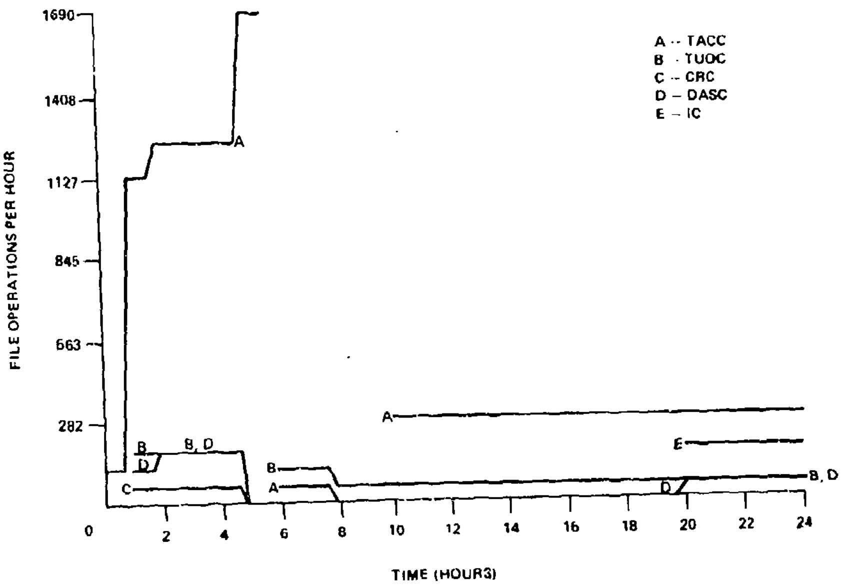

Figure 10. Component Activity Levels (STP1CAS)

IA-57,973

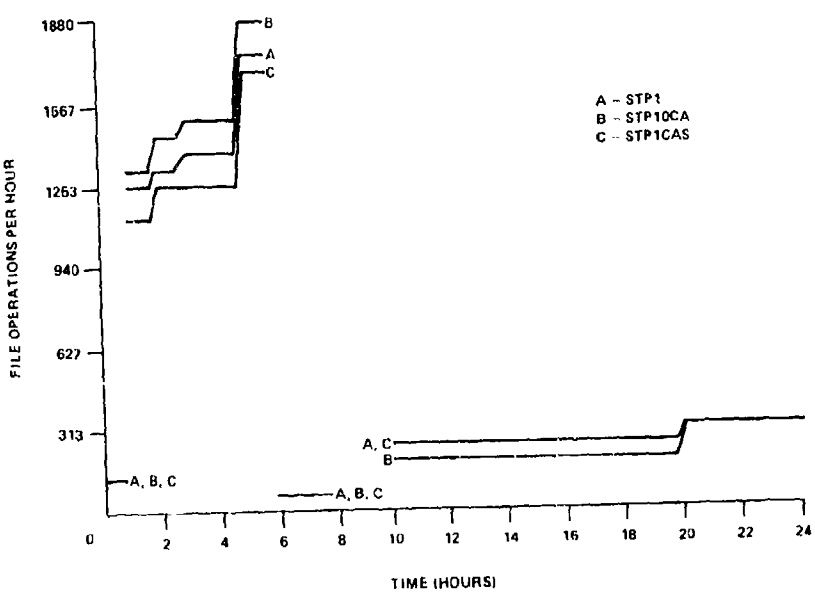

Figure 11. TACC Activity Levels

IA-57,972

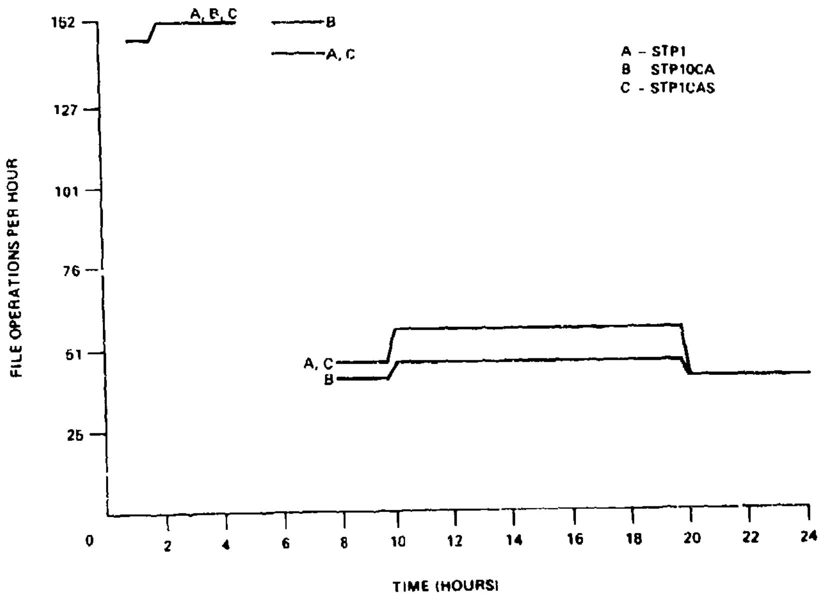

Figure 12. TUOC Activity Levels

IA-57,671

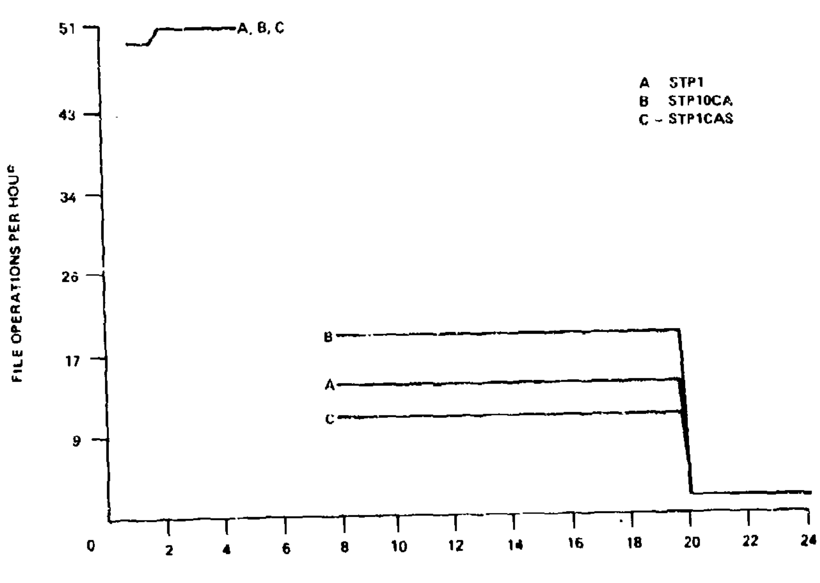

Figure 13. CRC Activity Levels

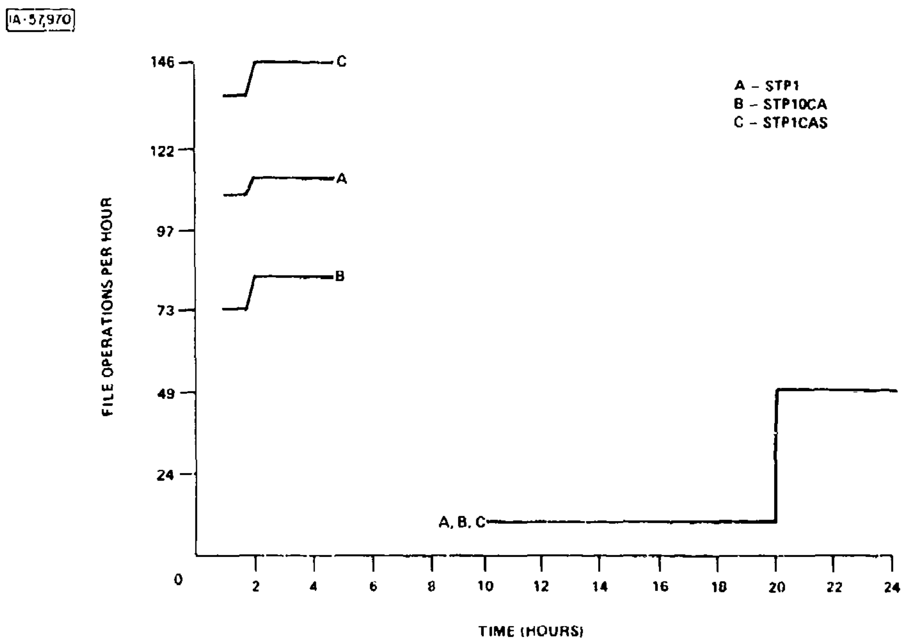

Figure 14. DASC Activity Levels

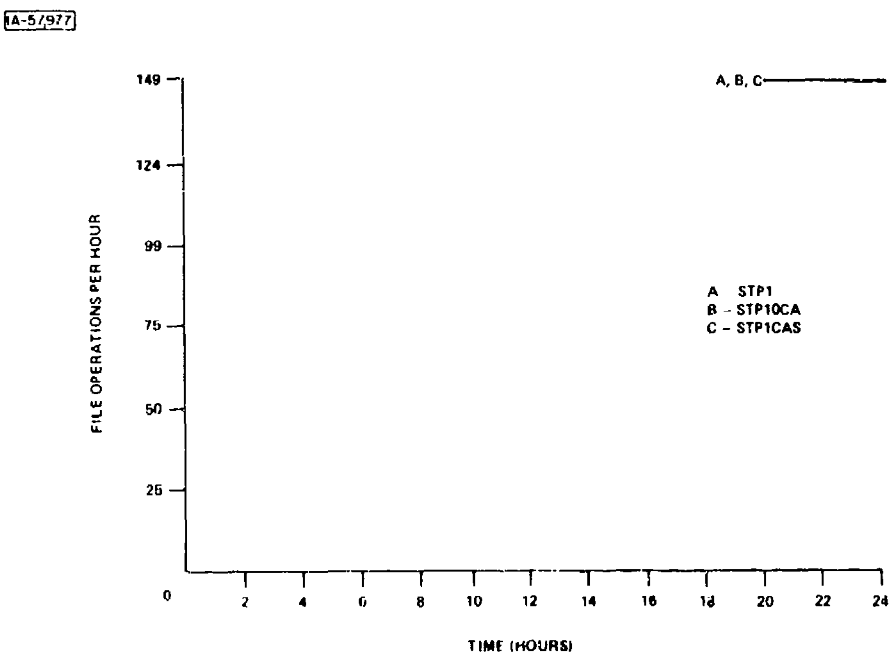

Figure 15. IC Activity Levels

SECTION 7

FILE ALLOCATION

The location of the data in a distributed database system is critical to the performance of the system. In this section we will show how the results of the basic model can be used to choose an optimal file allocation, and we will show how the file allocation can be incorporated in the model to provide quantitative data for the design of the communication and node processor subsystems.

The file allocation strategy chosen is largely dependent on the cost function used to establish optimality. The selection of an appropriate cost function is beyond the scope of this paper. However, in this section we will investigate two allocation strategies which seem intuitively reasonable, and which can be implemented with the information on hand. The two strategies are:

Source precedence - A file is stored at the node which is the most frequent source of record entry to the file.

Usage precedence - A file is stored at the node where the highest usage of the data in the file occurs.

SOURCE PRECEDENCE STRATEGY

The rationale behind the source precedence strategy is that insertion is the most difficult of the file operations, and this difficulty is compounded by performing the operation from a remote point in the network. This strategy is intended to minimize processing costs. Total daily counts of insertions to each file are tabulated in Tables 9 through 13 for each of the scenarios.

Two copies of each file are allocated to insure an increased degree of data survival. The copies are assigned to the two sources of highest insertion rates as determined from Tables 9 through 13. The TACC and CRC are used as alternate sites of assignment, since the TACC is the focus of functions being supported and the CRC is to serve as backup to the TACC. Thus, copies of the file are placed at the TACC and CRC, in that order, unless other sources have higher insertion rates. The results of this file allocation strategy are shown in Table 14. There was some concern that changing the scenario would change the results of the allocation strategy. However, this seems not to be a problem since all scenarios led to the same allocation.

Table 9

File Insertions for STP1 Scenario (Number of Insertions/Day)

File	Source				
	TACC	TUOC	CRC	DASC	IC
TARGET	123	0	0	45	0
MSN_REQ	0	0	0	183	595
SUP_MSN_REQ	18	0	0	0	0
MSN_SCHED	200	0	0	0	0
FLIGHT_SCHED	0	208	0	0	0
REPORT	0	4	170	3	0
IMMED_MSN_REQ	23	0	0	55	0
ALERT	0	78	0	0	0
CRITICAL_MUNITIONS	0	2	0	0	0
TACS_STATUS	0	0	0	0	0
AIRBASE_STATUS	0	0	0	0	0
AIRCRAFT_STATUS	0	96	0	0	0
SORTIE_AVAIL	32	0	0	0	0
SORTIE_RATE	0	0	0	0	0
OVERALL_APPORT	1	0	0	0	0
UNIT_APPORT	11	0	0	0	0
TNKR_ASGMNT	5	0	0	0	0

Table 10

File Insertions for STP1MAX Scenario (Number of Insertions/Day)

File	Source				
	TACC	TUOC	CRC	DASC	IC
TARGET	134	0	0	68	0
MSN_REQ	0	0	0	183	595
SUP_MSN_REQ	27	0	0	0	0
MSN_SCHED	302	0	0	0	0
FLIGHT_SCHED	0	313	0	0	0
REPORT	0	6	255	4	0
IMMED_MSN_REQ	34	0	0	83	0
ALERT	0	119	0	0	0
CRITICAL_MUNITIONS	0	2	0	0	0
TACS_STATUS	0	0	0	0	0
AIRBASE_STATUS	0	0	0	0	0
AIRCRAFT_STATUS	0	96	0	0	0
SORTIE_AVAIL	32	0	0	0	0
SORTIE_RATE	0	0	0	0	0
OVERALL_APPORT	1	0	0	0	0
UNIT_APPORT	11	0	0	0	0
TNKR_ASGMNT	8	0	0	0	0

Table 11

File Insertions for STP1MIN Scenario (Number of Insertions/Day)

File	Source				
	TACC	TUOC	CRC	DASC	IC
TARGET	118	0	0	36	0
MSN_REQ	0	0	0	183	595
SUP_MSN_REQ	5	0	0	0	0
MSN_SCHED	130	0	0	0	0
FLIGHT_SCHED	0	133	0	0	0
REPORT	0	2	89	2	0
IMMED_MSN_REQ	18	0	0	39	0
ALERT	0	56	0	0	0
CRITICAL_MUNITIONS	0	2	0	0	0
TACS_STATUS	0	0	0	0	0
AIRBASE_STATUS	0	0	0	0	0
AIRCRAFT_STATUS	0	96	0	0	0
SORTIE_AVAIL	32	0	0	0	0
SORTIE_RATE	0	0	0	0	0
OVERALL_APPORT	1	0	0	0	0
UNIT_APPORT	11	0	0	0	0
TNKR_ASGMNT	2	0	0	0	0

Table 12

File Insertions for STP1OCA Scenario (Number of Insertions/Day)

File	Source				
	TACC	TUOC	CRC	DASC	IC
TARGET	116	0	0	32	0
MSN_REQ	0	0	0	183	595
SUP_MSN_REQ	6	0	0	0	0
MSN_SCHED	200	0	0	0	0
FLIGHT_SCHED	0	197	0	0	0
REPORT	0	4	220	3	0
IMMED_MSN_REQ	16	0	0	42	0
ALERT	0	58	0	0	0
CRITICAL_MUNITIONS	0	2	0	0	0
TACS_STATUS	0	0	0	0	0
AIRBASE_STATUS	0	0	0	0	0
AIRCRAFT_STATUS	0	96	0	0	0
SORTIE_AVAIL	32	0	0	0	0
SORTIE_RATE	0	0	0	0	0
OVERALL_APPORT	1	0	0	0	0
UNIT_APPORT	11	0	0	0	0
TNKR_ASGMNT	5	0	0	0	0

Table 13

File Insertions for STP1CAS Scenario (Number of Insertions/Day)

File	Source				
	TACC	TUOC	CRC	DASC	IC
TARGET	116	0	0	52	0
MSN_REQ	0	0	0	183	595
SUP_MSN_REQ	27	0	0	0	0
MSN_SCHED	200	0	0	0	0
FLIGHT_SCHED	0	208	0	0	0
REPORT	0	4	137	3	0
IMMED_MSN_REQ	16	0	0	62	0
ALERT	0	78	0	0	0
CRITICAL_MUNITIONS	0	2	0	0	0
TACS_STATUS	0	0	0	0	0
AIRBASE_STATUS	0	0	0	0	0
AIRCRAFT_STATUS	0	96	0	0	0
SORTIE_AVAIL	32	0	0	0	0
SORTIE_RATE	0	0	0	0	0
OVERALL_APPORT	1	0	0	0	0
UNIT_APPORT	11	0	0	0	0
TNKR_ASGMNT	1	0	0	0	0

Table 14

File Locations (Source Precedence Strategy)

File	Location				
	TACC	TUOC	CRC	DASC	IC
TARGET	X			X	
MSN_REQ				X	X
SUP_MSN_REQ	X		X		
MSN_SCHED	X		X		
FLIGHT_SCHED	X	X			
REPORT		X	X		
IMMED_MSN_REQ	X			X	
ALERT	X	X			
CRITICAL_MUNITION	X	X			
TACS_STATUS	X		X		
AIRBASE_STATUS	X		X		
AIRCRAFT_STATUS	X	X			
SORTIE_AVAIL	X		X		
SORTIE_RATE	X		X		
OVERALL_APPORT	X		X		
UNIT_APPORT	X		X		
TNKR_ASGMNT	X		X		

USAGE PRECEDENCE STRATEGY

The rationale for the usage precedence strategy is that the total, system-wide cost of performing database operations is independent of the node at which they are performed. Hence, the only cost variable with file location is the communication cost. So, the optimal allocation minimizes the number of messages sent over the network by locating the file at the point of highest usage. Total daily counts of all file operations to each file are tabulated in Tables 15 through 19 for each scenario.

If we assume that the data critical to the operation of the node is the data most often used, then this strategy can be seen to have the additional benefit of tending to store critical data at the node. This would lead to a more functionally reliable system, since critical data would still be available as long as the node exists; regardless of loss of communications or loss of other nodes.

Again, two copies of each file are assigned, with the TACC and CRC as alternative sites. As before, we find that the file allocation does not depend on scenario. The allocation is shown in Table 20.

Table 15

Total File Activity for STP1 Scenario (Number of Insertions/Day)

File	Source					Total
	TACC	TUOC	CRC	DASC	IC	
TARGET	1133	0	0	45	0	1178
MSN_REQ	1258	0	0	183	595	2036
SUP_MSN_REQ	43	0	0	0	0	43
MSN_SCHED	2176	744	200	447	0	3567
FLIGHT_SCHED	280	527	0	0	0	807
REPORT	177	4	170	3	0	354
IMMED_MSN_REQ	226	0	0	55	0	281
ALERT	1516	244	0	0	0	1760
CRITICAL_MUNITIONS	4019	4	0	0	0	4023
TACS STATUS	6	48	6	6	0	66
AIRBASE STATUS	8	8	0	0	0	16
AIRCRAFT_STATUS	32	96	0	0	0	128
SORTIE_AVAIL	232	0	0	0	0	232
SORTIE_RATE	32	0	0	0	0	32
OVERALL APPORT	1	0	0	0	0	1
UNIT APPORT	11	0	0	0	0	11
TNKR_ASGMNT	24	0	0	0	0	24
TOTAL	11174	1675	376	739	595	14559

Table 16

Total File Activity for STP1MAX Scenario (Number of Insertions/Day)

File	Source					Total
	TACC	TUOC	CRC	DASC	IC	
TARGET	1599	0	0	68	0	1667
MSN_REQ	1682	0	0	183	595	2460
SUP_MSN_REQ	64	0	0	0	0	64
MSN_SCHED	3276	1123	302	674	0	5375
FLIGHT_SCHED	422	794	0	0	0	1216
REPORT	266	6	255	4	0	531
IMMED_MSN_REQ	339	0	0	83	0	422
ALERT	2274	370	0	0	0	2644
CRITICAL_MUNITIONS	6098	4	0	0	0	6102
TACS_STATUS	6	48	6	6	0	66
AIRBASE_STATUS	8	8	0	0	0	16
AIRCRAFT_STATUS	32	96	0	0	0	128
SORTIE_AVAIL	334	0	0	0	0	334
SORTIE_RATE	32	0	0	0	0	32
OVERALL_APPORT	1	0	0	0	0	1
UNIT_APPORT	11	0	0	0	0	11
TNKR_ASGMNT	37	0	0	0	0	37
TOTAL	16481	2449	563	1018	595	21106

Table 17

Total File Activity for STP1MIN Scenario (Number of Insertions/Day)

File	Source					Total
	TACC	TUOC	CRC	DASC	IC	
TARGET	838	0	0	36	0	874
MSN_REQ	987	0	0	183	595	1765
SUP_MSN_REQ	12	0	0	0	0	12
MSN_SCHED	1500	471	130	342	0	2443
FLIGHT_SCHED	158	307	0	0	0	465
REPORT	93	2	89	2	0	186
IMMED_MSN_REQ	167	0	0	39	0	206
ALERT	1194	172	0	0	0	1366
CRITICAL_MUNITIONS	1217	4	0	0	0	1221
TACS_STATUS	6	48	6	6	0	66
AIRBASE_STATUS	8	8	0	0	0	16
AIRCRAFT_STATUS	32	96	0	0	0	128
SORTIE_AVAIL	162	0	0	0	0	162
SORTIE_RATE	32	0	0	0	0	32
OVERALL_APPORT	1	0	0	0	0	1
UNIT_APPORT	11	0	0	0	0	11
TNKR_ASGMNT	8	0	0	0	0	8
TOTAL	6426	1108	225	608	595	8962

Table 18

Total File Activity for STP10CA Scenario (Number of Insertions/Day)

File	Source					Total
	TACC	TUOC	CRC	DASC	IC	
TARGET	1329	0	0	32	0	1361
MSN_REQ	1398	0	0	183	595	2176
SUP_MSN_REQ	19	0	0	0	0	19
MSN_SCHED	1980	753	200	327	0	3260
FLIGHT_SCHED	298	512	0	0	0	810
REPORT	227	4	220	3	0	454
IMMED_MSN_REQ	147	0	0	42	0	189
ALERT	1056	164	0	0	0	1220
CRITICAL_MUNITIONS	4271	4	0	0	0	4275
TACS_STATUS	6	48	6	6	0	66
AIRBASE_STATUS	8	8	0	0	0	16
AIRCRAFT_STATUS	32	96	0	0	0	128
SORTIE_AVAIL	232	0	0	0	0	232
SORTIE_RATE	32	0	0	0	0	32
OVERALL_APPORT	1	0	0	0	0	1
UNIT_APPORT	11	0	0	0	0	11
TNKR_ASGMNT	24	0	0	0	0	24
TOTAL	11071	1589	426	593	595	14274

Table 19

Total File Activity for STP1CAS Scenario (Number of Insertions/Day)

File	Source					Total
	TACC	TUOC	CRC	DASC	IC	
TARGET	1019	0	0	52	0	1071
MSN_REQ	1193	0	0	183	595	1971
SUP_MSN_REQ	62	0	0	0	0	62
MSN_SCHED	2185	744	200	579	0	3708
FLIGHT_SCHED	280	527	0	0	0	807
REPORT	144	4	137	3	0	288
IMMED_MSN_REQ	220	0	0	62	0	282
ALERT	1516	244	0	0	0	1760
CRITICAL_MUNITIONS	3800	4	0	0	0	3804
TACS_STATUS	6	48	6	6	0	66
AIRBASE_STATUS	8	8	0	0	0	16
AIRCRAFT_STATUS	32	96	0	0	0	128
SORTIE_AVAIL	232	0	0	0	0	232
SORTIE_RATE	32	0	0	0	0	32
OVERALL_APPORT	1	0	0	0	0	1
UNIT_APPORT	11	0	0	0	0	11
TNKR_ASGMNT	13	0	0	0	0	13
TOTAL	10754	1675	343	865	595	14252

Table 20

File Location (Usage Precedence Strategy)

File	Location				
	TACC	TUOC	CRC	DASC	IC
TARGET	X			X	
MSN_REQ	X				X
SUP_MSN_REQ	X		X		
MSN_SCHED	X	X			
FLIGHT_SCHED	X	X			
REPORT	X		X		
IMMED_MSN_REQ	X			X	
ALERT	X	X			
CRITICAL_MUNITIONS	X	X			
TACS_STATUS	X	X			
AIRBASE_STATUS	X	X			
AIRCRAFT_STATUS	X	X			
SORTIE_AVAIL	X		X		
SORTIE_RATE	X		X		
OVERALL_APPORT	X		X		
UNIT_APPORT	X		X		
TNKR_ASGMNT	X		X		

MESSAGE TRAFFIC

Once a file allocation has been chosen, each of the database operations may be viewed as a message sent by the node initiating the operation to the node (or nodes) where the file is located. Note that some of these messages may go from a node to itself. By keeping counts of these messages one can get a measure of the load on the logical links of the communication network. The load on the local database systems is reflected in the counts of incoming messages at the node.

When the operation is insertion, replacement, or deletion, a message must be sent to each node possessing a copy of a multiple copy file. This assures agreement among the copies of the file. Only one message is needed for a retrieval, but there should be some mechanism for choosing the optimal copy to retrieve. We will use the physical distance between nodes as a retrieval criterion since it should be roughly proportional to communication cost. A more accurate criterion would require more detailed design information.

The internode distance were derived from map coordinates provided by the physical deployment portion of the Korean training scenario. These coordinates have been normalized to a 100 x 100 grid. The resulting physical layout is represented in Figure 16. For the purpose of initial simplification, we have been considering the TUOC as a single node in the network, whereas the scenario specifies eight TUOCs. We will persist in this assumption by assigning a distance between the ficticious TUOC node and other nodes which is the average distance over all the TUOCs. The basis and conclusions of these calculations are shown in Table 21. All of the internode distances are tabulated in Table 22.

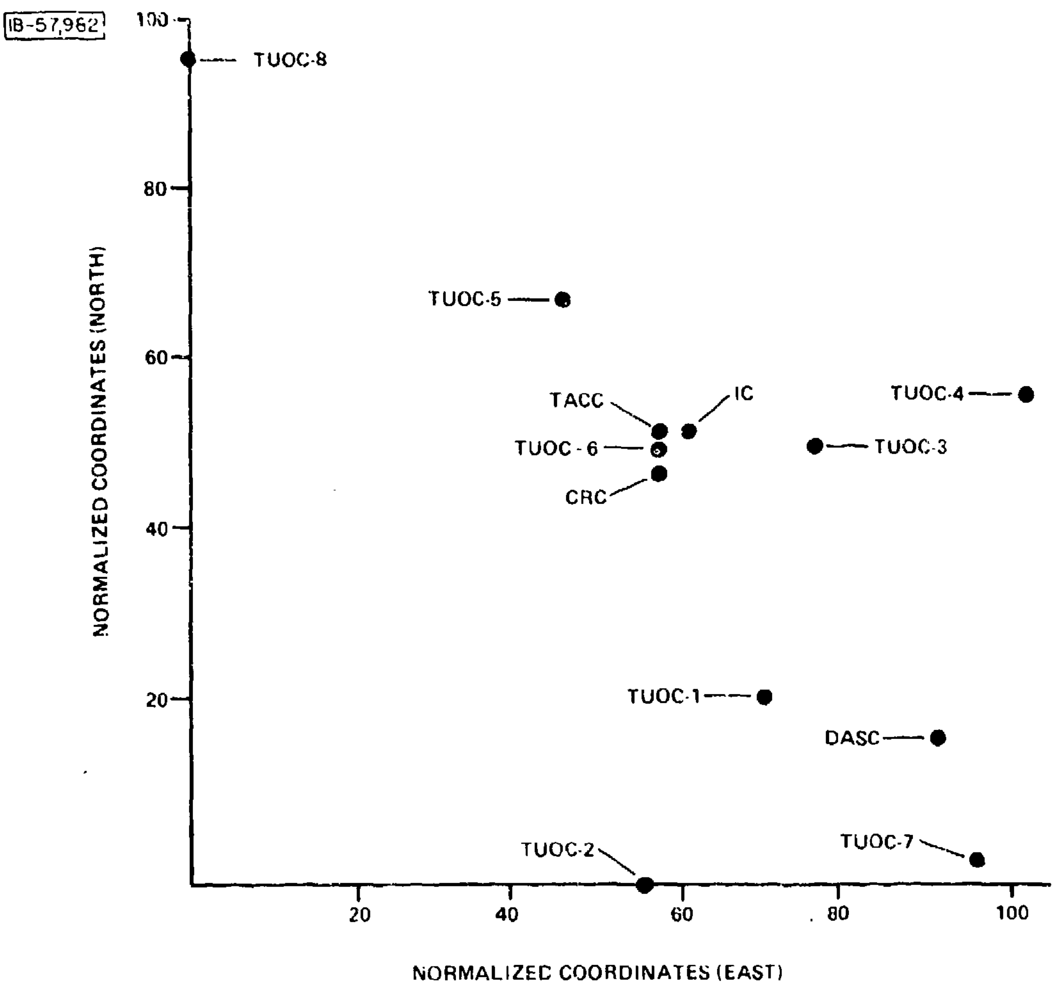

Figure 16. TACS Components - Physical Deployment

Table 21

Normalized Distances Between TUOC's and Components

TUOC	Component			
	TACC	CRC	DASC	IC
TUOC-1	32.7	30.4	22.9	31.6
TUOC-2	49.3	46.6	42.9	49.3
TUOC-3	23.4	23.5	34.5	21.2
TUOC-4	46.8	47.1	36.6	44.6
TUOC-5	20.0	22.3	69.3	21.2
TUOC-6	0.0	2.7	50.1	2.2
TUOC-7	63.8	61.9	15.8	62.4
TUOC-8	70.4	72.2	120.5	72.1
Average	38.3	38.3	49.1	38.1

Table 22

Inter-component Normalized Distances

	TACC	TUOC	CRC	DASC	IC
TACC	0.0	38.3	2.7	50.1	2.2
TUOC	38.3	0.0	38.3	49.1	38.1
CRC	2.7	38.3	0.0	48.5	3.5
DASC	50.1	49.1	48.5	0.0	48.4
IC	2.2	38.1	3.5	48.4	0.0

Network messages arise when a file is not located at the source of entry of a file operation. Table 23 shows network message traffic for each of the scenarios along with the percentage of file operations that cannot be performed at their source. The usage precedence strategy has a significant impact in lowering network message traffic as we would expect. The percentage of file operations requiring network involvement has been reduced by 10 points for all scenarios. It is interesting to note that this percentage rises as the number of missions drop from STP1MAX to STP1MIN. This is probably due to the increasing significance of the mission independent background and the apparent internode characteristic of that background.

Table 23

Daily Network Message Traffic

Scenario	Allocation Strategy			
	Usage Precedence		Source Precedence	
	Messages per Day	Percent of Total	Messages per Day	Percent of Total
STP1	4948	26.5	6790	36.4
STP1MAX	6542	24.7	9172	34.7
STP1MIN	3815	31.5	5101	42.1
STP1OCA	4619	25.4	6660	36.7
STP1CAS	5069	27.6	6813	37.1

For the design of the physical communication network, one would like information on the message loads on each of the logical links of the network. This information can be derived from the message count array. The numbers of messages from each source to each destination are shown in Tables 24 through 28 for each of the scenarios and both allocation strategies.

Table 24

Daily Component to Component Messages for STP1 Scenario

Destination	Source					Total (In)
	TACC	TUOC	CRC	DASC	IC	
Usage Precedence						
TACC	11174	935	376	295	228	13095
TUOC	874	1671	6	453	0	3092
CRC	465	4	170	3	0	642
DASC	347	0	0	100	0	447
IC	412	0	0	183	228	822
Total (Out)	13270	2786	552	1034	456	
Source Precedence						
TACC	9739	1759	6	109	0	11613
TUOC	405	963	170	3	0	1541
CRC	1111	64	376	456	0	2007
DASC	759	0	0	283	228	1270
IC	1257	0	0	183	228	1668
Total (Out)	13271	2786	552	1034	456	

Table 25

Daily Component to Component Messages for STP1MAX Scenario

Destination	Source					Total (In)
	TACC	TUOC	CRC	DASC	IC	
Usage Precedence						
TACC	16692	1456	563	444	345	19500
TUOC	1315	2567	6	680	0	4568
CRC	678	6	255	4	0	943
DASC	420	0	0	151	0	571
IC	623	0	0	279	345	1247
Total (Out)	19728	4029	824	1558	690	
Source Precedence						
TACC	14533	2567	6	161	0	17267
TUOC	609	1394	255	4	0	2262
CRC	1650	68	563	684	0	2965
DASC	104	0	0	430	345	1818
IC	1893	0	0	279	345	2517
Total (Out)	19728	4029	824	1558	690	

Table 26

Daily Component to Component Messages for STP1MIN Scenario

Destination	Source					Total (In)
	TACC	TUOC	CRC	DASC	IC	
Usage Precedence						
TACC	6206	712	225	197	80	7420
TUOC	551	1179	6	348	0	2084
CRC	280	2	89	2	0	373
DASC	304	0	0	75	0	379
IC	192	0	0	112	80	384
Total (Out)	7533	1893	320	734	160	
Source Precedence						
TACC	5346	1179	6	83	0	6614
TUOC	232	654	89	2	0	977
CRC	692	60	225	350	0	1327
DASC	496	0	0	187	80	763
IC	767	0	0	112	80	959
Total (Out)	7533	1893	320	734	160	

Table 27

Daily Component to Component Messages for STP1OCA Scenario

Destination	Source					Total (In)
	TACC	TUOC	CRC	DASC	IC	
Usage Precedence						
TACC	11085	990	426	193	339	13013
TUOC	766	1735	6	333	0	2840
CRC	491	4	220	3	0	718
DASC	291	0	0	74	0	365
IC	426	0	0	87	339	852
Total (Out)	13059	2729	652	670	678	
Source Precedence						
TACC	9446	1735	6	83	0	11270
TUOC	424	930	220	3	0	1577
CRC	1060	64	426	336	0	1886
DASC	717	0	0	161	339	1217
IC	1412	0	0	87	339	1838
Total (Out)	13059	2729	652	670	678	

Table 28

Daily Component to Component Messages for STP1CAS Scenario

Destination	Source					Total (In)
	TACC	TUOC	CRC	DASC	IC	
Usage Precedence						
TACC	10752	1023	343	413	123	12654
TUOC	914	1759	6	585	0	3264
CRC	446	4	137	3	0	590
DASC	334	0	0	114	0	448
IC	410	0	0	287	123	820
Total (Out)	12856	2786	486	1402	246	
Source Precedence						
TACC	9417	1754	6	123	0	11305
TUOC	372	963	137	3	0	1475
CRC	1132	64	343	588	0	2127
DASC	744	0	0	401	123	1268
IC	1191	0	0	287	123	1601
Total (Out)	12856	2786	486	1402	246	

The incoming file operation messages will determine the amount of processing power required at each of the nodes of the network. All incoming messages will invoke operations on files located at the node. We categorize the messages as native if they originate at the node with the file, or foreign if they originate elsewhere. The incoming message flow at each node for the STP1 scenario and usage precedence file allocation strategy is represented in Table 29.

Table 29

Incoming Message Flow (STP1, Usage Precedence)

Incoming Messages (TACC)								
	Foreign				Native			
File	INSERT	RETRIEVE	REPLACE	DELETE	INSERT	RETRIEVE	REPLACE	DELETE
TARGET	45	0	0	0	123	910	0	100
MSN_REQ	778	0	0	0	0	846	0	412
SUP_MSN_REQ	0	0	0	0	18	7	0	18
MSN_SCHED	0	200	7	0	200	1536	238	202
FLIGHT_SCHED	208	0	317	2	0	140	0	140
REPORT	177	0	0	0	0	0	0	177
IMMED_MSN_REQ	55	0	0	0	23	102	101	0
ALERT	78	0	0	166	0	1428	0	88
CRITICAL_MUNITIONS	2	0	0	2	0	4019	0	0
TACS_STATUS	0	0	60	0	0	0	6	0
AIRBASE_STATUS	0	0	8	0	0	8	0	0
AIRCRAFT_STATUS	96	0	0	0	0	32	0	0
SORTIE_AVAIL	0	0	0	0	32	0	200	0
SORTIE_RATE	0	0	0	0	0	32	0	0
OVERALL_APPORT	0	0	0	0	1	0	0	0
UNIT_APPORT	0	0	0	0	11	0	0	0
TNKR_ASGMNT	0	0	0	0	5	16	3	0

Table 29 (Cont'd)

Incoming Messages (TUOC)

File	Foreign INSERT	Foreign RETRIEVE	Foreign REPLACE	Foreign DELETE	Native INSERT	Native RETRIEVE	Native REPLACE	Native DELETE
MSN_SCHED	200	444	241	202	0	740	4	0
FLIGHT_SCHED	0	0	0	140	208	0	317	2
ALERT	0	0	0	88	78	0	0	166
CRITICAL_MUNITIONS	0	0	0	0	2	0	0	2
TACS_STATUS	0	0	18	0	0	0	48	0
AIRBASE_STATUS	0	0	0	0	0	0	8	0
AIRCRAFT_STATUS	0	0	0	0	96	0	0	0

Incoming Messages (CRC)

File	Foreign INSERT	Foreign RETRIEVE	Foreign REPLACE	Foreign DELETE	Native INSERT	Native RETRIEVE	Native REPLACE	Native DELETE
SUP_MSN_REQ	18	0	0	18	0	0	0	0
REPORT	7	0	0	177	170	0	0	0
SORTIE_AVAIL	32	0	200	0	0	0	0	0
SORTIE_RATE	0	0	0	0	0	0	0	0
OVERALL_APPORT	1	0	0	0	0	0	0	0
UNIT_APPORT	11	0	0	0	0	0	0	0
TNKR_ASGMNT	5	0	3	0	0	0	0	0

Table 29 (Concl'd)

Incoming Messages (DASC)								
	Foreign				Native			
File	INSERT	RETRIEVE	REPLACE	DELETE	INSERT	RETRIEVE	REPLACE	DELETE
TARGET	123	0	0	100	45	0	0	0
IMMED_MSN_REQ	23	0	101	0	55	0	0	0

Incoming Messages (IC)								
	Foreign				Native			
File	INSERT	RETRIEVE	REPLACE	DELETE	INSERT	RETRIEVE	REPLACE	DELETE
MSN_REQ	183	0	0	412	595	0	0	0

SECTION 8

SUMMARY AND CONCLUSIONS

In this paper we have described the design, implementation, and use of a mathematical model which relates user activity to the database load to support that activity. The model and extensions are used to investigate the application of distributed database technology to support the force management functions of a tactical air control system.

OBSERVATIONS

The results from the basic model show that, for the chosen scenario and operations concept, 70 to 80 percent of the database activity originates at the TACC. As one might expect, some of the load shifts to the DASC when the mission mix is skewed toward close air support missions since these missions involve the DASC far more than the other components. However, the shift is rather small.

The importance of file scanning in performance is indicated by the activity on the CRITICAL_MUNITIONS and ALERT files which are two of the most active. When an immediate mission request (IMMED_MSN_REQ) is entered, the ALERT file is scanned to determine whether any alert resources are suitable. This calls for six retrievals from the ALERT file (the average number of records in the ALERT file) to each insertion to IMMED_MSN_REQ. This ratio of one to six is approximately the ratio of the file activities of the two files as shown in Table 7.

The time line analysis of Section 6 reveals that the peak system load occurs during the fifth hour of the daily cycle as shown in Figure 7. This peak corresponds to the period of review of the frag order before it is finalized. There are from 1000 to 2500 file operations per hour during that peak period. This also appears to be the peak period for each of the individual components, as shown in Figures 11 through 15.

It is also observed from Figure 7 that changing the mission mix has a noticeable effect on the variation of file activity rate during the day. The time line employed breaks roughly into two periods - planning (0 - 8 hour) and monitoring (8 - 20 hour). Shifting toward offensive counter air missions yields about an 8 percent increase in planning activity and a 24 percent decrease in

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monitoring activity. Shifting toward close air support gives a 2 percent decrease in planning activity and no change in monitoring.

The information in Table 23 of Section 7, derived from the file allocation extension to the model, shows that network message traffic can be reduced by 25 to 30 percent with a usage precedence file allocation strategy as opposed to the source precedence strategy. The true significance of this reduction will be apparent only when more details of the implementation are considered, such as record length, message overhead, and communication and processing costs.

From Tables 24 through 28 it might appear that the TACC to TUOC communication channel is the busiest. However, this is not really the case since our TUOC node represents an aggregate of eight TUOC's. With this in mind, all channels appear to be under approximately the same message load.

Under either file allocation strategy - source precedence or usage precedence - the TACC has the highest number of incoming messages, and hence the heaviest file processing load. In fact, the load on the TACC is an order of magnitude greater than that on each of the other nodes. Again the true significance will emerge only when more implementation details are added.

It is true that usage precedence reduces message traffic, but at the cost of increased processing load at the TACC as shown by the total number of incoming messages to the TACC in Tables 24 through 28. So the comparative value of each strategy would have to be established.

CONCLUSIONS

Based on the data derived from this stage of modeling, there are very few apparent reasons for distributing the database. Since so much of the activity originates at the TACC, the tendency would be toward a centralized database located at the TACC with terminal access from the other nodes. The primary reason, however, for distribution of the data is to decrease vulnerability to destruction. This reason alone may be sufficient. Another plausible reason for distribution is to allow the TACC to shed some of its processing load onto other components.

The bias toward centralization is probably a result of the set of functional requirements used to construct the model; particularly, the set of files chosen and the view of user activity represented in the script file. The requirements were obtained from

system specifications for a centralized database for the TACC and reflect that approach. One of the areas for further work is the development of truly "distributed" system requirements. This could be done by assigning some of the TACC functions to lower echelon components (e.g., part of the mission scheduling done at wing level) or by providing for computer assistance to the functions intrinsic to the lower echelon components (e.g., computer assisted route planning at the TUOC). Such information has been difficult to obtain since it does not pertain to the current mode of organization.

One of the shortcomings of this study, due to its limited scope, is the failure to consider the full function of each of the components. For example, the CRC has many functions which do not relate directly to force management, but which would create a load on any computer and communication system used. Thus, to design the system based solely on the force management function would leave it woefully inadequate to support the totality of C3 functions. These sorts of difficulties had been anticipated and the model has been made flexible enough to permit adjustments.

The operational scenario under which the system is to run will have an effect on the loads. However, some of these effects do not seem to be as profound as had been imagined. The changes in mission levels induced some shifting of load, but the change was primarily an overall increase or decrease of database activity. This observation needs further investigation within different scenarios.

Another aspect of the operation which will have a significant impact on system design is the time line by which the functions are carried out. There appears to be no consensus on precisely what the time line should be. The time line used in this paper is a realistic representation of one approach to TACS operation in which the day's missions are planned and then executed. Another approach, giving a totally different time line, would be to plan the next day's mission while the current day's missions are being executed. The latter approach would probably distribute system activity more evenly over the day, leading to a lower peak load.

Results to date exhibit the use of the transaction workload model for a given operational setting. However, the approach taken to modeling provides a tool suitable for investigation of a wide range of operations concepts, scenarios and database distribution alternatives. Work is currently underway to establish a set of more distributed system requirements. Some additional scenario data has been obtained and is being used in the model. Other file allocation strategies, both heuristic and quantitative, are being considered. Message sizes are currently being derived to enable determination of load on communication channel.

REFERENCES

(LAMB78a) D. W. Lambert, "Preliminary Requirements for a Tactical C3 Distributed Database System," WP-21815, The MITRE Corp., Bedford, Mass., 14 June 1978.

(LAMB78b) D. W. Lambert, "Information Requirements for a Tactical C3 Distributed Database System (DDS)," WP-21965, The MITRE Corp., Bedford, Mass., 5 October 1978.

(ESDA77) System Specification for Tactical Air Control Center (TACC) Automation, SS-001485-13, Volume II of III, Electronic Systems Division, Air Force Systems Command, 485L Program Office, Hanscom AFB, Mass., 15 June 1977.

(NERA76) Capt. J. F. Nerad to OLAI/Lt. Col. Knedlik, TACC Automation System Level Test (Volume V) Frag Order Augmentation, Memorandum for Record, 8 October 1976.

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APPENDIX A

LOGICAL FILE STRUCTURE

The logical files employed in the information system were derived by unifying relational data structures of (LAMB78b). Whenever possible, similar data for differing mission types was unified. The succeeding tables relate the logical files to the more detailed relational data structures. The numeric entries in the tables refer to the relation numbers of (LAMB78b).

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Table A-1

Mission-Dependent Data (Relation Numbers from LAMB78b)

Mission Type	Logical File		
	MSN_REQ	MSN_SCHED	SUP_MSN_REQ
Preplanned Counter Air and Air Interdiction	1A, 2, 3	73, 29, 72, 14, 40, 17C, 59, 15C, 61, 16C	18C
Preplanned Close Air Support	4, 2A, 3A	14, 40, 16 26, 15, 59	17
Ground Alert Close Air Support and Air Interdiction	6, 8	14, 40, 16A	none
Air Alert Close Air Support and Air Interdiction	7, 8A	14, 40, 16A 15B	none
Ground Alert Reconnaissance	32, 8B	14, 40, 8B 52, 34	none
Preplanned Reconnaissance	35, 35B 36	14, 40, 36, 72, 59, 51, 54, 48, 73, 29	49
Ground Alert Air Defense	38	14, 40, 44	none
Air Alert Air Defense	39	14, 40, 46, 45	none
Support (Air Patrol and Escort)	none	24, 59, 60, 72, 73, 29, 23, 67, 68	none
Tanker	none	74, 73, 29, 28	none

Table A-1 (Concl'd)

Mission-Dependent Data (Relation Numbers from LAMB78b)

Mission Type	Logical File		
	REPORTS	FLIGHT_SCHED	IMMED_MSN_REQ
Preplanned Counter Air and Air Interdiction	101, 105	14A, 58	91
Preplanned Close Air Support	101, 106	14A, 22	91
Ground Alert Close Air Support and Air Interdiction	none	none	none
Air Alert Close Air Support and Air Interdiction	102	22A	none
Ground Alert Reconnaissance	none	none	none
Preplanned Reconnaissance	101, 107	14A, 51	92, 93
Ground Alert Air Defense	none	none	none
Air Alert Air Defense	102	65	none
Support (Air Patrol and Escort)	101, 108	14A, 66	none
Tanker	103, 109, 104	none	none

Table A-2

Files Independent of Mission Type (Relation Numbers from LAMB78b)

Logical File	Relations
TARGET	1
ALERT	81, 82, 83
CRITICAL_MUNITIONS	10A
TACS_STATUS	10B, 10C
AIRBASE_STATUS	10D, 10E
AIRCRAFT_STATUS	10
SORTIE_AVAIL	11
SORTIE_RATE	11A
OVERALL_APPORT	12
UNIT_APPORT	13
TNKR_ASGMNT	(none)

APPENDIX B

COMPUTER IMPLEMENTATION OF MODEL AND EXTENSIONS

This appendix will discuss some of the details of the computer implementation of the transaction workload model and derivation of the results presented in this paper. These programs were developed using computing facilities at RADC through the ARPANET. The programs were written in APL because of its array handling ability and its ability to evaluate character strings as computational expressions. The present implementation consists of three major segments - a basic model and two extensions. The extensions introduce the additional details of time lines and file allocation. A block diagram of the implementation is shown in Figure B-1.

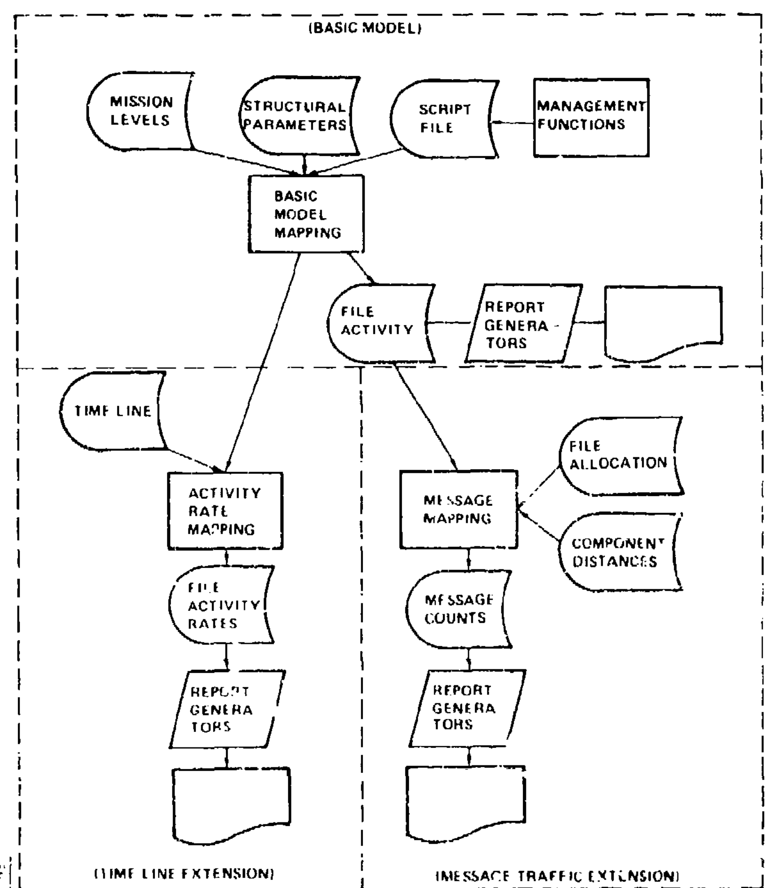

Figure B-1. Computer Implementation Diagram

BASIC MODEL

The input to the basic model is a 16-component vector of mission counts for the 24-hour period.

The output for the model is a three-dimensional file activity array. The array can be processed further to produce insights into a variety of aspects of performance. Or, the array can be processed in conjunction with additional data for a more detailed representation of system implementation.

The mapping from input to output is accomplished by a virtual file representing a script of operator actions. Each record has four fields:

(OPERATION, FILE, SOURCE, FREQUENCY)

The first three fields of each record index a position in the file activity array, while the fourth specifies an increment to that array position, computed from the input. The model program processes each record of the script file and accumulates increments to the file activity array toward the final value of the array.

Additional computational constants, called structural parameters, are employed in the FREQUENCY expressions for computing increments. These parameters are of two types and are generally related to the physical deployment of the system being modeled: the number of certain items in the deployment, such as the number of TUOC's deployed; average ratios between certain activities, such as the average number of air missions refueled by a tanker mission, or the average number of requests reviewed by a mission planner.

A number of computer functions are provided to facilitate creation and manipulation of the script file, and to tailor the output data to a variety of needs.

TIME LINES

The script file is segmented according to the operational phase to which the actions belong. Each segment contains all operator actions for a single operational phase. To superimpose a finer time line than the 24-hour period on the activities of the basic model, we assign a period of duration to each operational phase. The records of a single segment are processed, and the file activity array accumulated. The entries of the array are all divided by the duration of the phase corresponding to the segment just processed. This yields an array of file activity rates. We follow this procedure for each of the segments of the script file. To obtain

information about the situation at any time during the 24-hour cycle, we determine which phases are in operation at that time and process their file rate arrays according to our needs. Usually this involves generating a numeric array to be used by a graphics function.

These computations assume that the file activity rates are uniform, which is probably not realistic. It would seem reasonable to expect that planning rates decrease exponentially with time, while monitoring and adjustment rates would have Gaussian distributions. We could have accommodated these factors in the model, but they would have been purely speculative.

MESSAGE TRAFFIC

We collect counts of messages to measure network loads. The messages are classified by operation, file, source, and destination. For example, we will have a count of the number of INSERT messages to MSN_REQ file sent from the DASC to the CRC. These counts are assembled in an array similar to the file activity array, except that this array is indexed by quadruples rather than triples.

The message counts are obtained by processing our three-dimensional file activity array in conjunction with file location information and inter-component distances. The index of each count in the file activity array will supply the initial portion of an index into the message count array. We examine the file involved to supply the destination segment of the message count index. If the operation is other than retrieval, the destinations will be each of the components where a copy of the file is located. The file activity count is inserted at each of these indexed positions in the message count array. If the operation is retrieval, then the inter-component distances are consulted to determine the closest component with a copy of the file. That component is used as the single destination.

For example, suppose the count in the (INSERT, MSN_REQ, DASC) position of the file activity array is 43, and that copies of the file are located at the CRC and TACC. Then 43 will be entered in the (INSERT, MSN_REQ, DASC, CRC) and (INSERT, MSN_REQ, DASC, TACC) positions in the message count array. On the other hand, if the operation were RETRIEVE we would have to consult the inter-component distances to determine which is closer to the DASC, the CRC or TACC. If it is CRC, then only the (RETRIEVE, MSN_REQ, DASC, CRC) position receives the 43 from the file activity array.

Functions are provided to accomplish the mapping from the file activity array to the message counts array, and to further process the message array for tailored output.

SCRIPT FILE

The contents of the script file will be presented and explained by segment in Tables B-1 through B-10. The file is segmented according to the operational phase during which the operator actions occur (Primary Mission Planning, Force Allocation, etc.). The descriptions of the actions listed in Section 4 are repeated here for each operational phase, along with the file segment representing the actions. Any structural parameters used in the increment calculations will be explained. Their values are given in Table B-11. The structural parameters beginning with the prefix N_ represent the number of an item present in the deployment modeled. For example, N_TUOC is the number of TUOC's. The other parameters are named with a literal followed by two digits. The digits identify the phase to which the structural parameter pertains. The first digit identifies the major phase and the second digit the operational phase within that major phase. The literals within phases are then chosen to make the parameter unique. This naming convention is actually a relic of a previous organization of the work.

STRUCTURAL PARAMETERS

The values of the structural parameters used to derive the data for this paper are shown in Table B-11. These values were computed from the training scenario and assumed to extend to the other scenarios.

Table B-1

Script File Segment: FORCE ALLOCATION

Operator Actions				Description
1:	RETRIEVE	ABASE_STATUS	TACC N_TUOC	Status of each airbase is checked to determine whether or not sorties can be flown.
2:	RETRIEVE	ACRAFT_STATUS	TACC N_ACFTxN_TUOC	Status of aircraft/aircrew at each airbase is checked to determine the equipment available.
3:	RETRIEVE	SORTIE_RATE	TACC N_ACFTxN_TUOC	The sortie rate for each type of aircraft at each airbase is multiplied by the number of aircraft available at that airbase to give the number of sorties available.
4:	INSERT	SORTIE_AVAIL	TACC N_ACFTxN_TUOC	The computed number of sorties for each aircraft type at each airbase is stored.
5:	INSERT	OVERALL APPORT	TACC 1	The overall apportionment by mission type, which embodies command guidance, is stored.
6:	INSERT	UNIT_APPORT	TACC N_TUOCxAll	The distribution of sorties available at each airbase from each squadron among the mission types is stored.

Structural Parameters:

All = number of squadrons/airbase
N_TUOC = number of TUOC's
N_ACFT = number of aircraft types/TUOC

Table B-2

Script File Segment: PRIMARY MISSION PLANNING

Operator Actions				Description
1:	INSERT	MSN_SCHED	TACC +/H12xMSN	Planner inserts mission schedule for primary mission.
2:	RETRIEVE	MSN_REQ	TACC +/A12xMSN	Planner views a number of requests before deciding which request for a primary mission to fill.
3:	RETRIEVE	TARGET	TACC +/B12xMSN	Planner views target data for some or all of the requests viewed in #2.
4:	INSERT	SUP_MSN_REQ	TACC +/C12xMSN	Planner enters a request for a support mission, if it is needed.
5:	RETRIEVE	CRITICAL_MUNIT	TACC +/N_CMxD12xMSN	To make sure all munitions needed for a primary mission are available, the planner may scan the list of munitions in critical supply.
6:	REPLACE	SORTIE_AVAIL	TACC +/H12xMSN	As soon as a primary mission is scheduled, the planner subtracts the number of sorties used from the number of sorties available for subsequent primary missions.
7:	RETRIEVE	MSN_SCHED	DASC +/F12xMSN	When a mission has been planned, the DASC may want to review its mission schedule.
8:	RETRIEVE	MSN_SCHED	CRC +/E12xMSN	CRC reviews mission schedule.
9:	RETRIEVE	MSN_SCHED	TUOC +/G12xMSN	TUOC reviews mission schedule.

Structural Parameters:

A12 = mission requests viewed/mission planned
B12 = targets viewed/mission planned
C12 = requests for support/mission
D12 = scans of critical munitions list/mission planned
E12 = CRC review of mission schedule/mission
F12 = DASC review/mission
G12 = TUOC review/mission
H12 = 1 for each primary mission
N_CM = number of items on critical munitions list

Table B-3

Script File Segment: SUPPORT MISSION PLANNING

Operator Actions				Description
1:	INSERT	MSN_SCHED	TACC +/H13xMSN	Planner inserts mission schedule data for a support mission.
2:	RETRIEVE	SUP_MSN_REQ	TACC +/A13xMSN	Planner views a number of requests for support before deciding which one (or ones) to fill.
3:	RETRIEVE	MSN_SCHED	TACC +/B13xMSN	Planner views mission schedules of preplanned missions to be supported by the support mission being planned.
4:	RETRIEVE	CRITICAL_MUNIT	TACC +/N_CMxC13xMSN	The list of critical munitions may be scanned to make sure all munitions are available for the support mission being planned.
5:	REPLACE	SORTIE_AVAIL	TACC +/H13xMSN	Sorties used are subtraced from the sorties available.
6:	RETRIEVE	MSN_SCHED	TUOC +/E13xMSN	When the support mission has been planned, the TUOC may review the mission schedule for inconsistencies.
7:	RETRIEVE	MSN_SCHED	CRC +/F13xMSN	CRC reviews support mission schedule.
8:	RETRIEVE	MSN_SCHED	DASC +/G13xMSN	DASC reviews support mission schedule.

Structural Parameters:

A13 = support requests viewed/support mission planned
B13 = supported missions/support mission
C13 = munitions list scans/support mission planned
E13 = review of support mission schedule by TUOC/support mission
F13 = review by CRC/mission
G13 = review by DASC/mission
H13 = 1 for each support mission

Table B-4

Script File Segment: TANKER MISSION PLANNING

Operator Actions				Description
1:	INSERT	TNKR_ASGMNT	TACC +/B14xA14xMSN	Planner enters a tanker *assignment* into the database.
2:	RETRIEVE	MSN_SCHED	TACC +/(0≠A14)/MSN	Planner scans all missions to determine which will need refueling.
3:	RETRIEVE	MSN_SCHED	TACC +/B14xMSN	Planner views mission schedules of missions to be refueled by tanker being assigned.

Structural Parameters:

A14 = tanker missions/refueled missions
B14 = refueled missions/all missions

Table B-5

Script File Segment: FRAG ENTRY REVIEW

Operator Actions				Description
1:	RETRIEVE	MSN_SCHED	TACC +/A15xMSN	Each of the schedules will be reviewed at least once to insure overall consistency of the frag order.
2:	REPLACE	MSN_SCHED	TACC +/B15xA15xMSN	Some mission schedules reviewed may require alteration.
3:	RETRIEVE	MSN_REQ	TACC +/C15xA15xMSN	Mission requests may be rechecked.
4:	RETRIEVE	TARGET	TACC +/D15xA15xMSN	Target data may be rechecked.
5:	RETRIEVE	TNKR_ASGMNT	TACC +/E15xA15xMSN	The tanker assigned to the mission may be reviewed.
6.	REPLACE	TNKR_ASGMNT	TACC +/F15xE15xA15xMSN	Tanker assignment may require alteration.

Structural Parameters:

A15 = mission schedule reviews/mission
B15 = mission schedules altered/missions reviewed
C15 = mission requests reviewed/mission reviewed
D15 = targets reviewed/mission reviewed
E15 = tanker assignment reviews/mission review
F15 = tanker changes/tanker assignment review

Operator Actions				Description
1:	INSERT	FLIGHT_SCHED	TUOC +/B16xMSN	Each air mission must be assigned a flight schedule by the TUOC.
2:	RETRIEVE	MSN_SCHED	TUOC +/B16xMSN	The mission schedule of each air mission must be viewed at the TUOC before a flight schedule can be chosen.
3:	RETRIEVE	FLIGHT_SCHED	TACC +/A16xMSN	The planners at TACC may check the flight schedules for overall consistency.

Structural Parameters:

A16 = flight schedule reviews by TACC/mission
B16 = 1 for each mission type requiring a flight schedule

Table B-7

Script File Segment: OPERATION MONITORING

Operator Actions				Description
1:	REPLACE	MSN_SCHED	TUOC +/A21xMSN	Mission schedule is changed by the TUOC to reflect the reduced number of aircraft as the result of aborts.
2:	INSERT	REPORT	TUOC +/A21xMSN	TUOC enters an abort report.
3:	REPLACE	MSN_SCHED	DASC +/B21xMSN	Mission schedule changed by DASC as a result of abort.
4:	INSERT	REPORT	DASC +/B21xMSN	DASC enters an abort report.
5:	REPLACE	FLIGHT_SCHED	TUOC +/C21xMSN	Revised flight schedule as a result of air advisory entered by TUOC.
6:	REPLACE	FLIGHT_SCHED	TUOC +/D21xMSN	Flight schedule revised by TUOC as a result of ground delay.
7:	REPLACE	FLIGHT_SCHED	TUOC +/2xI21xMSN	Takeoff and landing reports are entered by TUOC on the flight schedule for each mission not cancelled.
8:	INSERT	REPORT	CRC +/B14xMSN	One refueling report is received and entered by CRC for each mission refueled.
9:	INSERT	REPORT	CRC +/E21xMSN	Inflight report received and entered by CRC.
10:	INSERT	REPORT	DASC +/F21xMSN	Inflight report entered by DASC.
11:	INSERT	REPORT	TACC +/G21xMSN	Inflight report entered by TACC.
12:	INSERT	ALERT	TUOC +/H21xMSN	Missions alerted are put on a current alert
13:	DELETE	ALERT	TUOC +/MSN+H21+H31 +I31	As missions go off alert without being activated, they are removed from the alert resources list by the TUOC.

Table B-7 (Concl'd)

Structural Parameters:

A21 = aborts reported by TUOC/mission
B21 = aborts reported by CRC/mission
C21 = air advisories/mission
D21 = ground delays/mission
E21 = inflight reports filed from CRC/mission
F21 = inflight reports filed from DASC/mission
G21 = inflight reports from TACC/mission
H21 = 1 for each alert mission
I21 = missions taking off/mission

Table B-8

Script File Segment: IMMEDIATE MISSION PLANNING

Operator Actions				Description
1:	INSERT	IMMED_MSN_REQ	TACC +/A31xMSN	Requests for immediate missions entered from the TACC.
2:	INSERT	IMMED_MSN_REQ	DASC +/M31xMSN	Request entered from the DASC.
3:	INSERT	TARGET	TACC +/B31xA31xMSN	Target data of corresponding immediate mission is entered by TACC.
4:	INSERT	TARGET	DASC +/C31xM31xMSN	Target data entered for DASC request.
5:	RETRIEVE	IMMED_MSN_REQ	TACC +/D31xMSN	Planner retrieves a number of immediate mission requests before deciding which to fill.
6:	RETRIEVE	TARGET	TACC +/E31xMSN	Planner views target data at least once for each request filled, but may also view targets in choosing request to process.
7:	RETRIEVE	ALERT	TACC N_ALERTx+/F31 xMSN	Planner scans list of alert resources to determine whether or not any of these are appropriate for the immediate mission request.
8:	RETRIEVE	MSN_SCHED	TACC +/L31xMSN	Planner views the mission schedule of an alert mission for possible activation.
9:	RETRIEVE	MSN_SCHED	TACC +/G31xMSN	Planner views mission schedules of preplanned missions for possible diversion.
10:	REPLACE	MSN_SCHED	TACC +/H31xMSN	Mission schedule of activated air alert mission is altered.
11:	REPLACE	FLIGHT_SCHED	TUOC +/H31xMSN	Flight schedule of activated air alert mission is updated.
12:	REPLACE	IMMED_MSN_REQ	TACC +/H31xMSN	Request marked filled.

Table B-8 (Concl'd)

Operator Actions				Description
13:	DELETE	ALERT	TACC +/H31xMSN	Air alert mission removed from the alert resources list.
14:	REPLACE	MSN_SCHED	TACC +/I31xMSN	Mission schedule for activated ground alert mission is alerted.
15:	INSERT	FLIGHT_SCHED	TUOC +/I31xMSN	Flight schedule for activated ground alert mission is entered by TUOC.
16:	REPLACE	IMMED_MSN_REQ	TACC +/I31xMSN	Request is marked filled.
17:	DELETE	ALERT	TACC +/I31xMSN	Ground alert mission is removed from the alert resources list.
18:	REPLACE	MSN_SCHED	TACC +/J31xMSN	Change mission schedule to divert preplanned mission.
19:	REPLACE	IMMED_MSN_REQ	TACC +/J31xMSN	Request is marked filled.
20:	REPLACE	FLIGHT_SCHED	TUOC +/K31xJ31xMSN	Update the flight schedule of diverted mission.
21:	REPLACE	TNKR_ASGMNT	TACC +/J31xMSN++ /B14xMSN	Adjust tanker assignment to fill refueling needs.
22:	REPLACE	MSN_SCHED	TACC +/J31xMSN++ /H13xMSN	Adjust support mission coordination.

Structural Parameters:

A31 = immediate mission requests from TACC/mission
B31 = targets supplied by TACC/immediate mission request
C31 = targets supplied by DASC/immediate mission request
D31 = request viewed/immediate mission
E31 = targets viewed/immediate mission
F31 = alert list scans/immediate mission
G31 = missions reviewed for diversion/immeidate mission
H31 = air alerts activated/immediate mission
I31 = ground alerts activated/immediate mission
J31 = missions diverted/immediate mission
K31 = flight schedules changed/diverted mission
L31 = air alert schedules reviewed/immediate mission
M31 = requests from DASC/mission
N_ALERT = average number of items on alert list

Table B-9

Script File Segment: OPERATION ADJUSTMENT

Operator Actions				Description
1:	DELETE	MSN_SCHED	TACC +/A32xMSN	Mission schedule of cancelled mission is removed by TACC.
2:	DELETE	FLIGHT_SCHED	TUOC +/B16xA32xMSN	Flight schedule of cancelled mission is removed by TUOC.
3:	DELETE	SUP_MSN_REQ	TACC +/C12xA32xMSN	Request for support mission required by cancelled mission is removed by TACC.
4:	REPLACE	MSN_SCHED	TACC +/A32xMSNx(+/H13x MSN)÷+/E32xMSN	Mission schedule of a mission supporting a cancelled mission is adjusted.
5:	REPLACE	TNKR_ASGMNT	TACC +/B14xA32xMSN	Assignment for a tanker mission refueling a cancelled mission is adjusted.
6:	REPLACE	MSN_SCHED	TACC +/B32xMSN	Mission schedule is adjusted.
7:	REPLACE	FLIGHT_SCHED	TUOC +/C32xMSN	Flight schedule is adjusted due to air or ground delay by TUOC.
8:	REPLACE	TNKR_ASGMNT	TACC D32x+/B14xA14xMSN	Tanker assignment adjusted to maintain rendezvous with delayed mission.

Structural Parameters:

A32 = cancellations/mission
B32 = mission schedule adjustment/mission
C32 = flight schedule changes/mission
D32 = tanker assignment changes/total refueled missions

Table B-10

Script File Segment: DATA MAINTENANCE

Operator Actions					Description
1:	REPLACE	TACS_STATUS	CRC	6xN_CRC	CRC enters status report.
2:	REPLACE	TACS_STATUS	TUOC	6xN_TUOC	TUOC enters status report.
3:	REPLACE	TACS_STATUS	DASC	6xN_DASC	DASC enters status report.
4:	REPLACE	TACS_STATUS	TACC	6xN_TACC	TACC enters status report.
5:	INSERT	ACRAFT_STATUS	TUOC	3xN_ACFTxN_TUOC	Each TUOC reports three times daily on the status of its aircraft and aircrews.
6:	REPLACE	ABASE_STATUS	TUOC	N_TUOC	Each TUOC reports daily on the status of the airbase equipment.
7:	INSERT	CRITICAL_MUNIT	TUOC	B41xN_CM	Munitions which have reached critically low levels are entered on a list.
8:	DELETE	CRITICAL_MUNIT	TUOC	B41xN_CM	Munitions which have been resupplied are removed from the critical munitions list.
9:	INSERT	MSN_REQ	DASC	+/A41xC41xMSN	Missions requests entered by DASC.
10:	INSERT	MSN_REQ	IC	+/D41xC41xMSN	Mission request entered by IC.
11:	INSERT	TARGET	TACC	N_TARGET	The target data for the next day's missions are entered in the database.
12:	DELETE	MSN_REQ	TACC	+/C41xMSN	Mission requests purged.
13:	DELETE	MSN_SCHED	TACC	+/MSNxH12+H13	Mission schedules purged.

Table B-10 (Concl'd)

14:	DELETE	TARGET	TACC N_TARGET	Old target list purged.
15:	DELETE	SUP_MSN_REQ	TACC +/C12xMSN	Support mission requests purged.
16:	DELETE	FLIGHT_SCHED	TACC +/B16xMSN	Flight schedule purged.
17:	DELETE	REPORT	TACC +/MSNxA21+B21+E21+ F21+G21+B14	Old reports purged.

Structural Parameters:

A41 = mission requests from DASC/mission requests
B41 = number of munitions changed/total on munitions list
C41 = mission requests/mission
D41 = mission requests from IC/mission requests
N_CRC = number of CRC's
N_TUOC = number of TUOC's
N_DASC = number of DASC's
N_ACFT = number of aircraft types/TUOC
N_TARGET = number of targets on target list

Table B-11

Structural Parameters

Mission Type	Parameters								
	A11	A12	B12	C12	D12	E12	F12	G12	H12
PREPLANNED OFFENSIVE COUNTER AIR		2.67	4.00	0.18	6.65	1.00	0.00	3.00	1.00
PREPLANNED AIR INTERDICTION		2.34	3.53	0.00	5.90	1.00	0.00	3.00	1.00
PREPLANNED CLOSE AIR SUPPORT		1.57	0.75	0.43	5.00	1.00	4.00	3.00	1.00
PREPLANNED RECONNAISSANCE		3.38	3.38	0.00	0.00	1.00	3.00	3.00	1.00
AIR ALERT AIR DEFENSE		0.42	0.00	0.00	5.00	1.00	0.00	3.00	1.00
AIR ALERT AIR INTERDICTION		0.62	0.00	0.00	5.00	1.00	0.00	3.00	1.00
AIR ALERT CLOSE AIR SUPPORT		0.30	0.00	0.00	5.00	1.00	4.00	3.00	1.00
GROUND ALERT AIR DEFENSE		0.83	0.00	0.00	5.00	1.00	0.00	3.00	1.00
GROUND ALERT AIR INTERDICTION		1.00	0.00	0.00	5.00	1.00	0.00	3.00	1.00
GROUND ALERT CLOSE AIR SUPPORT		0.30	0.00	0.60	5.00	1.00	4.00	3.00	1.00
GROUND ALERT RECONNAISSANCE		0.12	0.00	0.00	0.00	1.00	3.00	3.00	1.00
SUPPORT		0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00
IMMEDIATE OFFENSIVE COUNTER AIR		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IMMEDIATE AIR INTERDICTION		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IMMEDIATE CLOSE AIR SUPPORT		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IMMEDIATE RECONNAISSANCE		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISSION INDEPENDENT	1.37								

Table B-11 (Cont'd)

Mission Type	Parameters								
	A13	B13	C13	D13	E13	F13	G13	H13	A14
PREPLANNED OFFENSIVE COUNTER AIR	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.07
PREPLANNED AIR INTERDICTION	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.05
PREPLANNED CLOSE AIR SUPPORT	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
PREPLANNED RECONNAISSANCE	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
AIR ALERT AIR DEFENSE	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
AIR ALERT AIR INTERDICTION	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.25
AIR ALERT CLOSE AIR SUPPORT	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
GROUND ALERT AIR DEFENSE	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
GROUND ALERT AIR INTERDICTION	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.20
GROUND ALERT CLOSE AIR SUPPORT	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
GROUND ALERT RECONNAISSANCE	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
SUPPORT	1.10	3.38	5.00		3.00	1.00	4.00	1.00	0.00
IMMEDIATE OFFENSIVE COUNTER AIR	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
IMMEDIATE AIR INTERDICTION	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
IMMEDIATE CLOSE AIR SUPPORT	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
IMMEDIATE RECONNAISSANCE	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
MISSION INDEPENDENT				0.00					

Table B-11 (Cont'd)

Mission Type	Parameters								
	E14	*A15*	*B15*	*C15*	*D15*	*E15*	*F15*	*A16*	*B16*
PREPLANNED OFFENSIVE COUNTER AIR	1.00	3.00	0.15	1.33	1.33	0.07	0.20	1.00	1.00
PREPLANNED AIR INTERDICTION	1.00	3.00	0.15	1.18	1.18	0.06	0.00	1.00	1.00
PREPLANNED CLOSE AIR SUPPORT	0.00	3.00	0.56	0.75	0.75	0.00	0.00	1.00	1.00
PREPLANNED RECONNAISSANCE	0.00	3.00	0.15	1.69	1.69	0.00	0.00	1.00	1.00
AIR ALERT AIR DEFENSE	0.00	3.00	0.15	0.07	0.00	0.00	0.00	1.00	1.00
AIR ALERT AIR INTERDICTION	1.00	3.00	0.15	0.12	0.00	0.25	0.00	1.00	1.00
AIR ALERT CLOSE AIR SUPPORT	0.00	3.00	0.56	0.10	0.00	0.00	0.00	1.00	1.00
GROUND ALERT AIR DEFENSE	0.00	3.00	0.15	0.17	0.00	0.00	0.00	0.00	0.00
GROUND ALERT AIR INTERDICTION	1.00	3.00	0.15	0.20	0.00	0.00	0.00	0.00	0.00
GROUND ALERT CLOSE AIR SUPPORT	0.00	3.00	0.56	0.10	0.00	0.20	0.00	0.00	0.00
GROUND ALERT RECONNAISSANCE	0.00	3.00	0.15	0.03	0.00	0.00	0.00	0.00	0.00
SUPPORT	0.00	3.00	0.15	0.30	0.00	0.00	0.00	1.00	1.00
IMMEDIATE OFFENSIVE COUNTER AIR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IMMEDIATE AIR INTERDICTION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IMMEDIATE CLOSE AIR SUPPORT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IMMEDIATE RECONNAISSANCE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISSION INDEPENDENT									

Table B-11 (Cont'd)

Mission Type	Parameters								
	A21	B21	C21	D21	E21	F21	G21	H21	I21
PREPLANNED OFFENSIVE COUNTER AIR	0.03	0.01	0.01	0.01	1.00	0.00	0.00	0.00	0.98
PREPLANNED AIR INTERDICTION	0.03	0.01	0.01	0.01	1.00	0.00	0.00	0.00	0.98
PREPLANNED CLOSE AIR SUPPORT	0.03	0.01	0.01	0.01	1.00	0.00	0.00	0.00	0.98
PREPLANNED RECONNAISSANCE	0.03	0.01	0.01	0.01	1.00	0.00	0.00	0.00	0.98
AIR ALERT AIR DEFENSE	0.03	0.01	0.01	0.01	0.00	0.00	0.00	1.00	0.00
AIR ALERT AIR INTERDICTION	0.03	0.01	0.01	0.01	0.00	0.00	0.00	1.00	0.00
AIR ALERT CLOSE AIR SUPPORT	0.03	0.01	0.01	0.01	0.00	0.00	0.00	1.00	0.00
GROUND ALERT AIR DEFENSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
GROUND ALERT AIR INTERDICTION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
GROUND ALERT CLOSE AIR SUPPORT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
GROUND ALERT RECONNAISSANCE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
SUPPORT	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.98
IMMEDIATE OFFENSIVE COUNTER AIR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IMMEDIATE AIR INTERDICTION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IMMEDIATE CLOSE AIR SUPPORT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IMMEDIATE RECONNAISSANCE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISSION INDEPENDENT									

Table B-11 (Cont'd)

Mission Type	Parameters								
	A31	B31	C31	D31	E31	F31	G31	H31	I31
PREPLANNED OFFENSIVE COUNTER AIR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PREPLANNED AIR INTERDICTION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PREPLANNED CLOSE AIR SUPPORT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PREPLANNED RECONNAISSANCE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AIR ALERT AIR DEFENSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AIR ALERT AIR INTERDICTION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AIR ALERT CLOSE AIR SUPPORT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GROUND ALERT AIR DEFENSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GROUND ALERT AIR INTERDICTION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GROUND ALERT CLOSE AIR SUPPORT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GROUND ALERT RECONNAISSANCE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUPPORT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IMMEDIATE OFFENSIVE COUNTER AIR	0.00	0.00	0.00	0.00	0.00	0.00	2.73	0.00	0.00
IMMEDIATE AIR INTERDICTION	0.67	1.00	1.00	1.50	1.00	3.00	0.65	1.00	1.00
IMMEDIATE CLOSE AIR SUPPORT	0.00	0.00	1.00	1.50	1.00	3.00	0.70	1.00	1.00
IMMEDIATE RECONNAISSANCE	0.33	1.00	1.00	1.50	1.00	3.00	0.54	0.00	1.00
MISSION INDEPENDENT									

Table B-11 (Cont'd)

Mission Type	Parameters								
	J31	K31	L31	M31	A32	B32	C32	D32	E32
PREPLANNED OFFENSIVE COUNTER AIR	0.00	0.00	0.00	0.00	0.01	0.01	0.01		1.00
PREPLANNED AIR INTERDICTION	0.00	0.00	0.00	0.00	0.01	0.01	0.01		1.00
PREPLANNED CLOSE AIR SUPPORT	0.00	0.00	0.00	0.00	0.01	0.01	0.01		1.00
PREPLANNED RECONNAISSANCE	0.00	0.00	0.00	0.00	0.01	0.01	0.01		1.00
AIR ALERT AIR DEFENSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
AIR ALERT AIR INTERDICTION	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
AIR ALERT CLOSE AIR SUPPORT	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
GROUND ALERT AIR DEFENSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
GROUND ALERT AIR INTERDICTION	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
GROUND ALERT CLOSE AIR SUPPORT	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
GROUND ALERT RECONNAISSANCE	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
SUPPORT	0.00	0.00	0.00	0.00	0.01	0.01	0.01		0.00
IMMEDIATE OFFENSIVE COUNTER AIR	0.55	1.00	0.00	1.00	0.00	0.00	0.00		0.00
IMMEDIATE AIR INTERDICTION	0.12	1.00	6.50	0.32	0.00	0.00	0.00		0.00
IMMEDIATE CLOSE AIR SUPPORT	0.14	1.00	0.00	1.00	0.00	0.00	0.00		0.00
IMMEDIATE RECONNAISSANCE	0.10	1.00	2.00	0.66	0.00	0.00	0.00		0.00
MISSION INDEPENDENT								0.00	

Table B-11 (Cont'd)

Mission Type	Parameters			
	A41	B41	C41	D41
PREPLANNED OFFENSIVE COUNTER AIR	0.00		3.50	1.00
PREPLANNED AIR INTERDICTION	0.00		3.40	1.00
PREPLANNED CLOSE AIR SUPPORT	1.00		2.80	0.00
PREPLANNED RECONNAISSANCE	0.75		1.00	0.25
AIR ALERT AIR DEFENSE	0.00		3.50	1.00
AIR ALERT AIR INTERDICTION	0.00		2.50	1.00
AIR ALERT CLOSE AIR SUPPORT	1.00		4.00	0.00
GROUND ALERT AIR DEFENSE	0.00		4.00	1.00
GROUND ALERT AIR INTERDICTION	0.00		2.50	1.00
GROUND ALERT CLOSE AIR SUPPORT	1.00		4.00	0.00
GROUND ALERT RECONNAISSANCE	1.00		1.00	0.00
SUPPORT	0.00		0.00	0.00
IMMEDIATE OFFENSIVE COUNTER AIR	0.00		0.00	0.00
IMMEDIATE AIR INTERDICTION	0.00		0.00	0.00
IMMEDIATE CLOSE AIR SUPPORT	0.00		0.00	0.00
IMMEDIATE RECONNAISSANCE	0.00		0.00	0.00
MISSION INDEPENDENT		0.33		

Table B-11 (Concl'd)

Mission Type	Parameters								
	N_IC	N_TUOC	N_TARGET	N_DASC	N_TACC	N_CM	N_CRC	N_ACFT	N_ALERT
MISSION INDEPENDENT	1.00	8.00	100.00	1.00	1.00	7.00	1.00	4.00	7.00

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